



Lawrence Livermore National Laboratory
University of California
Livermore, California 94551

Department of Energy
Oakland Operations Office
Oakland, California 94612



Interim Record of Decision for the Building 834 Operable Unit Lawrence Livermore National Laboratory Site 300

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Environmental Protection Department
Environmental Restoration Division

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1. Declaration

1.1. Site Name and Location

The site described in this Interim Record of Decision (ROD) is known as the Building 834 operable unit (OU) located at Lawrence Livermore National Laboratory (LLNL) Site 300, Tracy, California. This OU is designated as OU-2 in the Federal Facility Agreement (FFA) signed in June 1992.

1.2. Statement of Basis and Purpose

This decision document presents the selected interim remedial action for the Building 834 OU at LLNL Site 300, Tracy, California. This remedial action was developed in accordance with the Comprehensive Environmental Response, Compensation and Liability Act (CERCLA), as amended by the Superfund Amendments and Reauthorization Act (SARA) and, to the extent practicable, the National Contingency Plan (NCP). This decision is based on the Administrative Record for this OU. The State of California Department of Toxic Substances Control (DTSC), Regional Water Quality Control Board (RWQCB), and the U.S. Environmental Protection Agency (EPA), Region IX, concur with the selected remedy.

The selected remedy set forth in this Interim ROD is intended only to address potential human inhalation risks resulting from volatilization of subsurface volatile organic compounds (VOCs). The following issues will be addressed in the Final (non-interim) ROD for the Building 834 operable unit:

1. Selection of supplemental innovative remedial technologies for remediation of subsurface dense nonaqueous phase liquid (DNAPL) and treatment of extracted soil vapor and ground water. These technologies have not yet been specifically identified, but will be evaluated concurrently with this interim action.
2. Ground water remediation strategy, ground water Applicable or Relevant and Appropriate Requirements (ARARs), and ground water cleanup goals.
3. Additional vadose zone remediation to protect ground water, if required.
4. Specific plans to monitor and protect the Tnbs₁ regional aquifer.
5. Potential cumulative effects of multiple contaminants.

1.3. Assessment of the Site

Based on the baseline risk assessment, actual or threatened releases of hazardous substances at this OU, if not addressed by implementing the response actions selected in this Interim ROD, may present an imminent and substantial endangerment to public health and welfare, or the environment.

1.4. Description of the Selected Remedy

In June 1992, an FFA for the LLNL Site 300 Experimental Test Facility was signed by the U.S. EPA Region IX, DTSC, RWQCB, and the U.S. Department of Energy (DOE). The FFA (as amended in 1995) defines seven OUs and designates the Building 834 OU as OU-2. The

Building 834 OU is located on a north-south-trending ridge in the southeastern portion of Site 300. The OU was established to address soil and ground water contamination in the subsurface immediately beneath and approximately 1,500 ft downgradient of the Building 834 Complex. Presently, the Site 300 FFA is being amended and the total number of OUs may be reduced. The amendment process should be completed before December 1995, but is not expected to affect the Building 834 OU.

Interim actions for the Building 834 OU primarily target trichloroethylene (TCE) in shallow perched ground water and soil beneath the core of the Building 834 Complex; secondarily, they address contamination caused by other VOCs, diesel fuel, and tetra 2-ethylbutylorthosilicate (T-BOS). The primary potential risk associated with contamination at the Building 834 OU is on-site worker inhalation exposure to TCE volatilizing from contaminated subsurface soil (0.5–12.0 ft) in the vicinity of the release sites.

Current analytical data and ground water fate and transport modeling indicate that the regional aquifer will not be affected by any contaminants at the OU. DOE/LLNL will continue to monitor ground water in the perched water-bearing zone and regional aquifer.

The major components of the selected remedy include:

- Installation of additional dedicated soil vapor monitoring points to monitor the progress of remediation.
- Sealing and abandonment of several existing ground water monitor wells.
- Installation of replacement ground water monitor wells.
- Modification of ventilation systems in selected buildings to increase air circulation and reduce any potential inhalation risk from TCE vapors that may be migrating into buildings from subsurface soil.
- Institutional exposure controls such as fences, warning signs, and excavation and/or construction restrictions, if required.
- Surface water drainage controls, such as asphalt paving, to reduce recharge of precipitation to the perched water-bearing zone.
- Light nonaqueous-phase liquid (LNAPL) extraction and treatment (T-BOS and diesel) to reduce the mass of these contaminants. Extracted LNAPLs will be removed from ground water using an oil-water separator, skimmer, or equivalent system.
- Soil vapor extraction (SVE) and treatment. Extracted soil vapor will be treated using granular activated carbon (GAC) or other technology. The interim soil vapor restoration level (ISVRL) is 250 ppm_{v/v} TCE, which corresponds to a TCE soil concentration of 2.2 mg/kg. Modeling indicates that this goal will be reached in approximately 5 years.
- Partial dewatering of the perched water-bearing zone in the vicinity of the release areas to enhance the effectiveness of SVE by exposing a larger soil volume to vapor flow. Extracted ground water will be treated by a low-profile type (or similar type) air stripper with GAC emissions control. Treated ground water will be discharged through an air misting system. Effluent concentrations of TCE and total VOCs will meet the substantive requirements of the California RWQCB. Effluent will be treated below limits of detection established for EPA Methods 601 and 602. Effluent concentrations for total petroleum hydrocarbons (TPH) as gasoline, TPH as diesel, and T-BOS will also be set at concentrations agreed to by the regulatory agencies and DOE/LLNL. Because this Interim ROD addresses only soil vapor with respect to inhalation risk and NAPL remediation, it does not include any cleanup goals for *in situ* ground water in the perched

water-bearing zone or cleanup goals for soil and soil vapor to protect ground water; these goals will be addressed in the Final ROD.

- Innovative technology development for enhanced removal of undissolved TCE DNAPL in the vadose zone and in shallow perched ground water. The objective will be to identify technologies that shorten cleanup time, improve cleanup efficiency, and reduce cost. Criteria to evaluate the effectiveness of any innovative technologies utilized will be developed with the regulatory agencies during the remedial design.

As presented in the *Final Feasibility Study (FS) for the Building 834 OU* (Landgraf et al., 1994) the 1994 present-worth cost of the selected remedy is estimated to be approximately \$10.38 million. This estimate assumes 2 years of LNAPL recovery, 5 years of SVE and dewatering, and 30 years of soil vapor and ground water monitoring. These time and cost estimates do not include the development or testing of any innovative technologies.

During the June 23, 1994, Site 300 Remedial Project Manager's Meeting, DOE/LLNL, RWQCB, DTSC, and U.S. EPA agreed to pursue a remedial action alternative for the Building 834 OU that included the testing and evaluation of innovative technologies combined with SVE and dewatering. Because no proven technology is currently available to remediate subsurface DNAPL, DOE/LLNL will test innovative technologies under this interim action and may choose one or more to be implemented in the final remedy. Such technologies may include alcohol flooding, surfactants, dual-gas partitioning tracers, bioremediation, and *in situ* radio frequency heating.

During this interim action, DOE/LLNL may also test innovative treatment technologies to reduce waste mass, waste volume, and overall cost. Such technologies may include electron accelerator destruction, resin adsorption, and ozone treatment. Any testing and implementation of such technologies must be approved by the regulatory agencies.

As remediation progresses, soil vapor samples will be collected from SVE wells and soil vapor monitoring points. The remediation system will be shut down when no soil vapor sample exceeds the ISVRL concentration. Monitoring will be conducted for four consecutive quarters after ISVRLs are met. If soil vapor concentrations increase above an acceptable level, the SVE system will be restarted. In addition to the soil vapor sampling, DOE/LLNL may also conduct direct soil vapor flux and/or ambient air measurements during the interim action to verify that the selected remedy is indeed protective of human health.

Prior to December 31, 1995, DOE/LLNL and the regulatory agencies will jointly determine the scope and schedule of all required post Interim ROD documents and reports (up to the Final ROD), as well as schedules for implementing the selected interim remedy.

1.5. Statutory Determinations

The interim action is protective of human health and the environment in the short term, and provides adequate protection until a final remedy for this OU is selected and presented in the Final (non-interim) ROD. The remedy complies with Federal and state applicable or relevant and appropriate requirements for this limited-scope action, and is cost-effective. Although this interim action is not intended to address fully the statutory mandate for permanence and treatment to the maximum extent practicable, it does utilize treatment; thus, it contributes to that statutory mandate. This action does not constitute the final remedy for the Building 834 OU. The statutory preference for remedies that employ treatment that reduces toxicity, mobility, or volume as a principal element, although partially addressed in this remedy, will be addressed by the final response action. Subsequent actions are planned to address fully the threats posed by conditions at this OU. Because this remedy will result in hazardous substances remaining on site above health-based levels, a review will be conducted within 5 years after commencement of the remedial action to ensure that the remedy continues to provide adequate protection of human

health and the environment. Because this is an Interim ROD, review of this site and of this remedy will be ongoing as DOE/LLNL and the regulatory agencies develop the final remedy for the Building 834 OU.

1.6. Signature and Support Agency Acceptance of the Remedy

Julie Anderson	Date
Director of Federal Facilities Cleanup Office	
Hazardous Waste Management Division	
U.S. Environmental Protection Agency	
Region IX	

Barbara Cook	Date
Chief, Region II Site Mitigation Branch	
State of California Department of Toxic Substances Control	

William H. Crooks	Date
Executive Officer	
State of California Regional Water Quality Control Board	
Central Valley Region	

James M. Turner, Ph.D.	Date
Manager	
Oakland Operations Office	
U.S. Department of Energy	

2. Decision Summary

2.1. Site Name, Location, and Description

Site 300, a DOE-owned experimental test facility operated by LLNL, is located in the southeastern Altamont Hills of the Diablo Range, about 17 mi east-southeast of Livermore and 8.5 mi southwest of Tracy, California (Fig. 1). The site is bordered by cattle grazing land, a California Department of Fish and Game ecological preserve, an outdoor recreational facility, and a privately owned high explosives (HE) testing facility. For the purpose of this Interim ROD, it is understood that Site 300 will remain under the continued control of DOE for the foreseeable future.

The Building 834 operable unit (OU) is located on a north-south-trending ridge in the southeastern part of Site 300, and was established to address soil and ground water contamination in the subsurface below the facility (Figs. 2 and 3). However, to address potential human inhalation risks, we discuss only soil remediation in this Interim ROD.

2.2. Site History and Enforcement Activities

Prior to the purchase of Site 300 land for development as a DOE HE test facility, the Building 834 area was used for cattle ranching and livestock grazing. Since the late 1950s, the Building 834 facilities have been used to expose test specimens to thermal shock, thermal cycling, and long-term elevated or reduced temperatures.

TCE served as the primary heat transfer fluid for these operations until the entire system was dismantled between September 1993 and May 1994. DOE/LLNL estimates that about 550 gallons of TCE, a suspected human carcinogen, leaked and spilled to the ground surface and a nearby septic system leach field, primarily between 1962 and 1978, contaminating the soil and shallow ground water in the area. Other chemical compounds commonly detected in the perched ground water in the Building 834 area include tetrachloroethylene (PCE), 1,2-dichloroethylene (DCE), 1,1,1-trichloroethane (TCA), T-BOS, and diesel fuel.

In 1982, DOE/LLNL discovered the contamination at the site and began an investigation under the guidance of the RWQCB. All investigations of potential chemical contamination at Site 300 were conducted under the oversight of the Central Valley RWQCB until August 1990, when Site 300 was placed on the National Priorities List (NPL). Since then, all investigations have been conducted in accordance with CERCLA under the guidance of three supervising regulatory agencies: the U.S. EPA Region IX, the RWQCB, and the DTSC. The DOE entered into an FFA with these agencies in June 1992.

In April 1994, LLNL released the *Final Site-Wide Remedial Investigation* (SWRI) report (Webster-Scholten, 1994). In July 1994, the *Final Building 834 Operable Unit Feasibility Study* (FS) (Landgraf et al., 1994) was published. The SWRI and the FS form the basis for selecting technologies for the remediation of subsurface contamination at the Building 834 OU. The Proposed Plan (PP) for the remediation of the Building 834 OU, which summarizes site conditions and remedial alternatives, was released in December 1994. The public comment period on the FS and PP was conducted between January 9 and February 9, 1995.

Since the discovery of contamination at Building 834, some of the VOCs in the subsurface have been remediated by soil excavation, soil venting, and ground water extraction and treatment. In addition, this facility has already been used as a test bed for several innovative technology treatability projects, including an EPA Superfund Innovative Technology Evaluation

(SITE) test of a PURUS™ pulsed ultraviolet soil vapor treatment system, an electrical soil heating pilot test (joule heating), and a demonstration of an electron accelerator to treat soil vapor (Matthews et al., 1992).

2.3. Highlights of Community Participation

The SWRI report and the FS for the Building 834 OU were made available to the public in April 1994 and July 1994, respectively. The PP was released to the public in December 1994. This Interim ROD presents the selected remedial action for the Building 834 OU. All documents were prepared in compliance with CERCLA as amended by SARA. The decision for this site is based on the Administrative Record, which is available at the Information Repository at the LLNL Visitors Center and the Tracy Public Library.

A public review and comment period on the preferred remedial alternative began January 9, 1995, and ended February 9, 1995. Interested members of the public were invited to review all documents and comment on the considered remedial alternatives by writing to the Site 300 Remedial Project Manager or by attending a public meeting on January 24, 1995, at the Tracy Inn in Tracy, California. At this meeting, representatives from DOE, LLNL, U.S. EPA, and the State of California discussed the proposed remediation plan and addressed public concerns and questions. Questions and comments from the public are discussed in the Responsiveness Summary of this Interim ROD.

2.4. Scope and Role of the Building 834 Operable Unit (OU)

The 1992 FFA (as amended in 1995) defines the following seven OUs at Site 300:

- OU-1, General Services Area (GSA).
- OU-2, Building 834.
- OU-3, Pit 6.
- OU-4, High Explosives Process Area Building 815.
- OU-5, Building 850/Pits 3 and 5.
- OU-6, Building 832 Canyon.
- OU-7, Site 300 Monitoring.

Investigations at the Building 834 OU address soil and ground water contaminated by VOCs, diesel, and T-BOS from past chemical spills and overfilling of an underground diesel storage tank. The principal potential threat to human health and the environment is exposure to VOC vapors volatilizing from shallow soil into ambient air.

This Interim ROD addresses only the potential human health inhalation risk posed by VOC contamination in the vadose zone at the Building 834 OU. The purpose of the selected remedy is to protect human health and the environment by reducing VOC concentrations in soil vapor and controlling contaminant migration.

2.5. Site Characteristics

Since environmental investigations began at the Building 834 Complex in 1982, 13 exploratory boreholes have been drilled and 48 ground water monitor wells have been completed. Two water-bearing zones have been identified (Fig. 4):

- **Perched Water-Bearing Zone:** The small, shallow perched water-bearing zone occurs beneath the OU. Depending on topography, depth to water is approximately 10–70 ft

beneath the ground surface. As a result of past releases, this perched water is contaminated with TCE and other VOCs, diesel, and T-BOS.

- **Regional Aquifer:** The regional aquifer occurs in the lower Neroly Formation (Tnbs₁). This semi-confined aquifer is encountered at 325 ft below the ground surface.

The TCE plume in the perched water-bearing zone at the Building 834 OU is separated from the regional aquifer by over 280 ft of unsaturated bedrock. Data indicate that the perched zone contaminant plume has not affected the regional aquifer.

2.5.1. Chemical Releases

Historical information and analytical data suggest that VOCs and LNAPLs (diesel and T-BOS) were released to the ground from surface spills, discharges to a septic tank, and leakage from pipes, pumps, and valves between the early 1960s and mid-1980s. These releases include:

- VOCs in the Building 834 OU near the core of the Building 834 Complex site and at the facility septic system. The quantity of TCE released in these areas greatly exceeds that of other VOCs. Based on employee interviews, we estimate that a total of about 550 gallons of TCE was released.
- TCE at the decommissioned septic system leach field.
- Diesel fuel in ground water attributed to accidental overfilling of an underground tank located near Building 834B.
- T-BOS concurrently released with the TCE as a mixture. T-BOS is added to TCE-based heat exchange fluids to preserve pump seals.

2.5.2. VOCs in Ground Water

TCE is the most prevalent VOC in ground water within the perched water-bearing zone and perching horizon. Other VOCs that have been detected include PCE, cis-1,2-DCE, 1,1,1-TCA, acetone, benzene, chloroform, 1,1-DCE, ethylbenzene, Freon 113, methylene chloride, toluene, and xylenes (total isomers) (Table 1).

Figure 5 shows the distribution of TCE in perched ground water beneath the Building 834 OU. The width of the plume varies from about 200 ft at the southern end to about 500 ft in the area of the former septic system leach field. Perched ground water beneath the Building 834 OU is characterized as limited in extent, shallow (10–70 ft below ground surface), and relatively thin (2–5 ft saturated thickness). The eastern and western extent of TCE in ground water is limited by the extent of saturation in the perched water-bearing zone. The plume extends from the core area southward for about 1,500 ft. We estimate the volume of contaminated ground water to be 2,400,000 gallons.

Historically, the core area (Buildings 834B, C, and D) and former septic tank leach field area have shown the highest concentrations of TCE in perched ground water. The maximum historical TCE concentration in the plume is 800,000 µg/L. This concentration suggests that TCE as residual DNAPL is present in the subsurface. The high TCE concentrations in ground water, soil, and soil vapor strongly suggest that TCE DNAPL may be present at and downgradient of the release sites. Environmental investigations conducted since 1982 indicate that the TCE ground water plume is of limited extent and relatively stable (i.e., not migrating downgradient) due to natural evapotranspiration. The shallow perched ground water at the Building 834 OU contains TCE and other chemicals of concern. Data indicate that shallow ground water is perched upon low-permeability siltstones and claystones, which prevent vertical migration to the semi-confined regional aquifer approximately 325 ft below the ground surface. No contamination from the perched water-bearing zone has been detected in the regional aquifer.

2.5.3. VOCs in Soil/Rock

Maximum TCE concentrations in borehole soil and rock samples are shown in Figures 6 and 7. TCE in vadose zone soil is mainly confined to the core area of the complex, near Buildings 834B, C, and D. The vertical and lateral variability of TCE concentrations in the core area is attributed to multiple releases, release amounts, and release occurrences, as well as lithologic heterogeneity and the amount of time that has passed since the releases occurred. The maximum concentrations of TCE in soil and rock mostly occur within 5 ft above or below the contact between the perched water-bearing zone and the perching horizon.

The maximum TCE concentration in soil (12,000 mg/kg) was detected in a soil sample collected in 1982 from a depth of 3.2 ft in the vicinity of a former TCE overflow drain behind Building 834C. At that time, TCE contaminated soil behind the building was excavated, aerated, and replaced with clean soil. The next highest TCE concentration (970 mg/kg) was found in the vicinity of Building 834D at a depth of 29.2 ft. Other than TCE, no other chemicals have been detected in soil and rock samples south of well W-834-T4.

Low concentrations of other VOCs reported in subsurface soil (0.5–12.0 ft) include PCE, Freon 11, benzene, ethylbenzene, toluene, and xylenes (total isomers) (Tables 2, 3, and 4). These VOCs are detected in concentrations ranging from 0.0002 to 14 mg/kg, the highest being PCE in a shallow (< 5 ft) soil sample collected from behind Building 834D. PCE is common in soil and rock samples from wells adjacent to Building 834D and in the borehole for well W-834-J1; it has not been detected in soil samples collected south of well W-834-S5. Toluene, benzene, ethylbenzene, and xylenes (total isomers) have primarily been detected in soil samples collected in the vicinity of Building 834D and the well W-834-T2 wells to the south. Freon 11 detection in soil samples is mostly limited to low concentrations in the vicinity of Building 834D and the former septic tank leach field.

2.5.4. VOCs in Soil Vapor

Active vacuum induced soil vapor surveys (SVSSs) were conducted between February and March 1989 to identify the extent of VOC contamination and to monitor the progress of vacuum extraction pilot studies (Fig. 8 and Table 5). The SVS sample results and the soil and rock analytical data confirm that releases of TCE occurred adjacent to pump station Buildings 834B, C, and D.

2.5.5. Diesel in Ground Water and Soil/Rock

Diesel fuel detected in ground water and soil at the core of the Building 834 Complex is attributed to accidental overfilling of the underground diesel fuel tank. A TPH concentration of 100 mg/kg was detected at a depth of 20 ft in a soil sample from the borehole of well W-834-D8, located near the diesel tank. Maximum fuel hydrocarbon concentrations in ground water range from 25,000 to 73,000 µg/L, depending on the analytical method used.

2.5.6. T-BOS in Ground Water

T-BOS, a LNAPL, was mixed with TCE to lubricate and preserve the pump seals. This LNAPL has been observed floating in samples collected from well W-834-D3 and in the tank used to collect ground water during previous pilot testing of the remediation system near Building 834D. T-BOS may also be trapped in vadose zone and saturated zone soil pores.

2.6. Risk Assessment

The baseline risk assessment evaluated potential present and future public health and ecological risks associated with environmental contamination in the Building 834 OU, using the assumption that no cleanup or remediation activities would take place at the site. Selection of a specific remediation strategy is based in part on the extent to which it can reduce potential public health and ecological risks.

The baseline risk assessment presented in the SWRI consisted of six components:

- Identification of the contaminated environmental media.
- Identification of chemicals of potential concern.
- Estimation of potential exposure-point concentrations of contaminants.
- Human exposure and dose assessment.
- Toxicity assessment.
- Risk characterization.

2.6.1. Identification of Contaminated Environmental Media

Based on our assessment of the nature and extent of contamination obtained during site characterization efforts, we identified contaminants of potential concern in four different environmental media in the Building 834 OU: surface soil, subsurface soil, soil vapor, and perched ground water.

2.6.2. Identification of Chemicals of Potential Concern

Table 6 presents the chemicals of potential concern identified in the Building 834 OU. Details of the methodology used to identify these contaminants are described in the SWRI.

2.6.3. Estimates of Exposure-Point Concentrations

We developed conceptual models to identify the probable migration processes of the chemicals of concern from release sites and source media in the Building 834 OU to selected potential exposure points. The conceptual models provided the basis for selection of the quantitative models used to generate estimates of contaminant release rates and potential exposure-point concentrations. The exposure-point concentrations were used to estimate the magnitude of potential exposure to contaminants in the baseline risk assessment. The release areas, migration processes, and exposure points identified in the Building 834 OU are given in Table 6. In addition, this table lists the mathematical models used to estimate contaminant migration rates and the potential exposure-point concentrations for the chemicals of concern in each environmental medium.

We applied a mathematical model to estimate the potential exposure-point concentrations of contaminants: 1) in the atmosphere when VOCs volatilize from subsurface soil (0.5 to 12.0 ft) in the vicinity of the Building 834D pump station, and 2) into indoor air of Building 834 when VOCs volatilize from subsurface soil underneath the building and diffuse into the building. A worst-case exposure scenario is assumed to occur in these locations because these are the regions for which the highest contaminant concentrations detected in subsurface soil have been reported.

In addition, we estimated the concentrations of surface soil (≤ 0.5 ft) contaminants bound to resuspended particles throughout the OU. The potential exposure-point concentrations for direct dermal contact and incidental ingestion of contaminants in surface soil are the same as the 95% upper confidence limits (UCLs) of the mean concentration of the chemicals.

The California Department of Forestry well, CDF-1, located approximately 300 ft southeast of the Site 300 boundary, was selected as the receptor location for modeling of ground water contaminants that originate in the Building 834 OU. An analytic model was used to estimate the concentration of TCE in ground water predicted to reach the exposure point, well CDF-1.

2.6.4. Human Exposure and Dose Assessments

Exposure scenarios and pathway exposure factors (PEFs) used to define potential human exposure and dose assessments are described below.

2.6.4.1. Exposure Scenarios

The exposure scenarios that we used to evaluate potential adverse health effects associated with environmental contamination in the Building 834 OU were developed with respect to a series of assumptions about present and future uses of the site and lands in the immediate vicinity.

We developed two principal scenarios to evaluate potential human exposure to environmental contaminants in the Building 834 OU. The first of these scenarios pertains to adults working in the Building 834 OU. This scenario addresses potential health risks attributable to contaminants in subsurface soil and surface soil, where an adult on site (AOS) is presumed to work in the immediate vicinity of the contamination over their entire period of employment at the site (25 years). Subsurface soil contaminants can volatilize into the atmosphere, where they may be inhaled by individuals who work in the vicinity of the contamination. Surface soil contaminants bound to resuspended soil particulates may also be inhaled by individuals in the course of work-related activities at the site. In addition, we evaluated AOS exposure as a consequence of dermal absorption and incidental ingestion of contaminants present on surface soil.

Our second scenario pertains to residential exposures (RES), which are associated exclusively with use of contaminated ground water from well CDF-1. The identification and selection of exposure pathways related to residential use of contaminated ground water were based on the assumption that well water will be used to supply all domestic water needs, such as those associated with showering or bathing, cooking, dishwashing, and laundry. Accordingly, we evaluated potential residential exposure to contaminants in ground water at CDF-1 due to 1) direct ingestion of water, 2) inhalation of VOCs that volatilize from water to indoor air, 3) dermal absorption of contaminants while showering or bathing, and 4) ingestion of homegrown beef, milk, and fruits and vegetables raised using contaminated ground water. For the purpose of the risk assessment, we assume residents could be exposed to contaminants in ground water for 30 years.

2.6.4.2. Pathway Exposure Factors

To estimate the magnitude of potential human exposure to contaminants in the Building 834 OU, we developed PEFs, which convert the exposure-point concentrations of contaminants into estimates of average contaminant intake over time (the chronic daily intake or CDI). These PEFs are based on a series of reported and/or assumed parameters regarding current and potential land use patterns in and around the Building 834 OU, residential occupancy patterns, and length of employment. PEFs also account for a number of physiological and dietary factors such as the daily ingestion rates of water and homegrown fruits, vegetables, beef, and milk; daily breathing rate; and surface area of exposed skin.

The PEFs that we used to evaluate potential adult on-site and residential exposure to contaminants are presented in Tables 7 through 16.

2.6.5. Toxicity Assessment

For each location with environmental contamination, we began by identifying those chemicals of concern that are classified by the U.S. EPA as carcinogens (U.S. EPA, 1992c). This classification is based on consideration of data from epidemiological studies, animal bioassays, and *in vivo* and *in vitro* tests of genotoxicity. The three principal weight-of-evidence classifications are Group A (human carcinogen), Group B (probable human carcinogen), and Group C (possible human carcinogen). Placement of a chemical in Group A requires positive evidence of carcinogenicity from occupational or epidemiological studies. Such data are generally not available for chemicals classified as Group B or Group C carcinogens. For chemicals in these latter two groups, the preponderance of evidence of carcinogenicity typically comes from animal studies.

2.6.5.1. Cancer Potency Factors

The Cancer Potency Factors (CPFs) used in our estimations of cancer risk were obtained from values published in either the Integrated Risk Information System (IRIS) (U.S. EPA, 1992c), the Health Effects Assessment Summary Tables (HEAST) (U.S. EPA, 1992b,c), or by the State of California, Environmental Protection Agency (1992). We also had CPFs for TCE and PCE provided by Region IX of the U.S. EPA (1993). All CPFs were derived using versions of the linearized, multistage dose-response model (U.S. EPA, 1989a,b); generally, the dose- and tumor-incidence data used in the model are from animal bioassays. For contaminants of potential concern at Site 300, the exceptions are cadmium and beryllium, where human tumor data are available. The model calculates the potential increased cancer risk, where increased risk is linearly related to dose for low-dose levels typical of environmental exposure. Use of animal bioassay data to predict human tumorigenic response assumes that animals are appropriate models of human carcinogenic response, and that the dose-response relationships observed in high-dose animal bioassays can be extrapolated linearly to the low doses generally associated with human exposure to environmental contaminants. When CPFs were available for a particular contaminant from both a U.S. EPA source and the State of California, we selected the highest potency from among the set of values.

The CPFs (slope factors) used to calculate cancer risks in our evaluation are presented in Tables 7 through 11.

2.6.5.2. Reference Dose

The reference doses (RfDs) that we used to evaluate potential noncarcinogenic adverse health effects were based, when possible, on long-term (i.e., chronic) exposures, and were derived by dividing an experimentally-determined no-observed-adverse-effect-level (NOAEL) or lowest-observed-adverse-effect-level (LOAEL) (each has units of mg/[kg • d]) by one or more uncertainty factors (U.S. EPA, 1992b,c,d). Each of these uncertainty factors has a value that ranges from 1 to 10 (U.S. EPA, 1992b,c,d). We selected pathway-specific RfDs, when available (U.S. EPA, 1992b,c,d and Cal-EPA, 1992), to calculate a corresponding Hazard Quotient (HQ). If pathway-specific RfDs were not available, we used the published RfD (typically developed for oral exposures) to calculate an HQ for all exposure pathways.

The reference doses used to calculate noncancer hazard indices in our evaluation are presented in Tables 12 through 16.

2.6.6. Risk Characterization

The risk assessment was performed in accordance with Risk Assessment Guidance for Superfund (RAGS) (U.S. EPA, 1989a,b). Carcinogenic risks, an evaluation of potential noncarcinogenic exposure health hazards, and the additivity of response are described below.

2.6.6.1. Carcinogenic Risks

For carcinogens, we calculated the potential incremental cancer risk associated with long-term exposure to chemicals present in surface soil, subsurface soil, and ground water. For each chemical at each exposure location, the total risk attributable to that chemical was determined by multiplying each pathway-specific intake (e.g., the dose due to ingestion of water or to inhalation of contaminant that volatilizes from water to indoor air) by the corresponding pathway-specific CPF. The products of each pathway-specific intake and pathway-specific CPF were summed to obtain the potential incremental cancer risk for a specific chemical. We completed parallel sets of calculations for all chemicals at each exposure location, then summed values of chemical-specific risk from all chemicals present to yield an estimate of total incremental risk for exposures associated with a given location.

2.6.6.2. Evaluation of Hazard from Exposure to Chemicals that Cause Noncancer Health Effects

For chemicals of potential concern that are not classified as carcinogens, and for those carcinogens known to cause adverse health effects other than cancer, we evaluated the potential for exposure to result in noncarcinogenic adverse health effects by comparing the CDI with a RfD. When calculated for a single chemical, this comparison yields an HQ. For each chemical at each location, we summed pathway-specific HQs (where applicable) to obtain an HQ for a given chemical. We then summed all HQs from all chemicals to yield an HI for potential exposures associated with a given location.

2.6.6.3. Additivity of Response

In every location at or near the Building 834 OU where we calculated potential cancer risk and noncancer HQs, CDIs were estimated for exposures attributable to multiple pathways for each of several contaminants. As noted previously, we estimated the total potential cancer risk and/or total HI by summing risk or HQs for all contaminants at a given location, where each chemical-specific estimate of risk or hazard represents potential exposures from multiple pathways. Implicit in the summation of risk and hazard is the assumption that the effects of exposure to more than one chemical are additive. This simplifying assumption does not consider similarities or differences in target organ toxicity, mechanism(s) of action, or the possibility of synergistic or antagonistic effects of different chemicals in the mixture.

2.6.7. Summary of Baseline Risks and Hazards Associated with Contaminants

Baseline risks and hazards for the Building 834 OU were evaluated for adult on-site exposures, additive potential risk and hazard for adults on site, and residential exposures. These are described below, followed by a brief discussion of uncertainty.

2.6.7.1. Adult On-Site Exposures

We evaluated potential AOS exposure to this contamination by calculating the associated risk and hazard for two different scenarios: 1) inhalation of VOCs that volatilize from subsurface soil to the atmosphere in the immediate vicinity of the building; and 2) inhalation of VOCs that volatilize from subsurface soil underneath the building followed by diffusion into the building air. Both AOS exposure scenarios resulted in estimates of individual potential excess lifetime cancer risk (6×10^{-4} and 1×10^{-3}) and noncancer HI (22 and 36) that exceed acceptable limits (U.S. EPA, 1990b).

Adults on site working in the Building 834 OU can potentially be exposed to contaminants present in surface soil. This exposure could occur if an individual inhales resuspended

contaminated particulates, comes in direct dermal contact with surface soil, or ingests small quantities of surface soil incidental to working in the area. Calculation of the risks associated with these exposures yielded estimates of total risk of 4×10^{-7} (inhalation of resuspended particulates) and 4×10^{-10} (ingestion and dermal absorption of surface soil contaminants). The corresponding total HIs are 7.2×10^{-5} and 1.1×10^{-2} .

The calculations of potential cancer risk are presented in Tables 7 through 16 and the results are summarized in Tables 17 through 20.

2.6.7.2. Additive Risk and Hazard for Adults On Site

Adults working outdoors in the vicinity of Building 834D could be exposed simultaneously to contaminants present in surface soil (by inhalation of resuspended particulates, and ingestion and dermal absorption of surface soil contaminants) as well as by inhalation of the VOCs that volatilize from subsurface soil into the atmosphere in the immediate vicinity of Building 834D.

Table 21 presents the estimated potential additive risk and HI for this scenario, as well as the contributions attributable to each source or transport medium. The values given in Table 21 indicate an estimated total risk of 6×10^{-4} and a total HI of 22. Both the total risk and the total HI are dominated by contaminants present in subsurface soil near Building 834D and are not substantially affected by contributions to risk or HI from surface soil contaminants.

2.6.7.3. Residential Exposures

We evaluated potential residential exposure to contaminants in ground water at well CDF-1 due to direct ingestion of water from the regional aquifer; inhalation of VOCs that volatilize from water to indoor air; dermal absorption of contaminants while showering or bathing; and ingestion of homegrown beef, milk, fruits, and vegetables raised using contaminated ground water. The calculations, presented in Tables 11 through 16 and summarized in Table 22, indicate the total potential excess lifetime excess cancer risk attributable to residential use of ground water is 7×10^{-11} , and the corresponding total HI is 2.8×10^{-6} .

2.6.7.4. Uncertainty in the Baseline Public Health Assessment

Uncertainties are associated with all estimates of potential carcinogenic risk and noncarcinogenic hazard. For example, the exposure parameters recommended by the U.S. EPA (1990a and 1991a) are typically obtained from the 90th or 95th percentile of a distribution; they are not necessarily representative of an average individual or of average exposure conditions. Consequently, use of upper-bound parameters may contribute to overly conservative estimates of potential exposure, and of risk and hazard.

2.6.8. Remedial Goals

To evaluate which remedial strategies would reduce potential public health risks in the Building 834 OU, we developed health-based PRGs. The baseline risk assessment identified subsurface soil/soil vapor in the vicinity of Building 834D as the only contaminated environmental medium in the Building 834 OU associated with an elevated risk or hazard. We applied the method presented in RAGS, Part B (U.S. EPA, 1991b) to derive health-based PRG concentrations which, if present in subsurface soil, would be protective of human health and the environment. The fundamental equation given in this method involves setting the total potential risk or hazard at a target level and solving for the concentration term. A concentration of 2.2 mg/kg TCE in soil is equivalent to an HI of 1. RAGS indicates that an HI greater than 1 may be associated with noncarcinogenic adverse health effects. The potential excess lifetime cancer risk associated with inhalation of TCE vapors, which volatilize from subsurface soil containing 2.2 mg/kg of TCE, is 3×10^{-5} . For known or suspected carcinogens, acceptable exposure levels

are generally concentration levels that represent an excess upper bound lifetime cancer risk to an individual of between 10^{-4} and 10^{-6} using information between dose and response. The 10^{-6} risk level shall be used as the point of departure for determining remediation goals for alternatives when ARARs are not available or are not sufficiently protective because of the presence of multiple contaminants at the site or multiple pathways of exposure. The 10^{-4} to 10^{-6} risk range is generally acceptable for risk management decisions. The method, calculations and parameters used to derive the health-based PRG for the Building 834 OU are presented in the Building 834 FS. The range of health-based PRGs we calculated in our evaluation is presented in Table 23. This table also presents the preliminary remediation goals for TCE in soil proposed by Region IX, U.S. EPA (1994).

As shown in Table 23, the concentration of TCE in subsurface soil associated with an HI of 1 is 2.2 mg/kg. This concentration is lower than the U.S. EPA Region IX PRGs for both industrial and residential soil (1994). To monitor the progress of subsurface soil remediation, we will analyze soil vapor samples from SVE wells and soil vapor monitor points, rather than attempting to collect soil samples. DOE/LLNL may also conduct direct soil vapor flux measurements in the future.

To convert a soil concentration of 2.2 mg/kg to a soil vapor concentration in ppm_{v/v}, we use the following equations:

$$C_{s-vapor} = C_s \times \frac{1}{K_d} \times \frac{H}{RT} \times 10^3$$

where,

$$C_{s-vapor} = \text{ISVRL-equivalent concentration of TCE in soil vapor } (1.348 \times 10^3 \frac{\text{mg}}{\text{M}^3}),$$

$$C_s = \text{concentration of TCE in soil (2.2 mg/kg),}$$

$$K_d = \text{adsorption coefficient of TCE in soil } (6.4 \times 10^{-1} \frac{\text{L}}{\text{kg}}),$$

$$H = \text{Henry's Law constant } (9.58 \times 10^{-3} \text{ atm} \cdot \frac{\text{M}^3}{\text{mole}}),$$

$$R = \text{ideal gas constant } (8.2 \times 10^{-5} \frac{\text{atm} \cdot \text{M}^3}{\text{mole} \cdot \text{degrees Kelvin}}),$$

$$T = \text{temperature (298 degrees Kelvin), and}$$

$$10^3 = \text{conversion factor;}$$

and,

$$C_{s-vapor \ v/v} = \frac{C_{s-vapor} \times 10^3 \times T \times R}{W \times P \times V}$$

where,

$$C_{s-vapor \ v/v} = \text{ISVRL concentration of TCE in soil vapor (250 ppm}_{v/v}\text{),}$$

$$10^3 = \text{conversion factor,}$$

$$W = \text{molecular weight of TCE } (131.4 \frac{\text{g}}{\text{mole}})$$

$$P = \text{pressure (1 atm), and}$$

$$V = \text{volume (1 M}^3\text{).}$$

Thus, the ISVRL is set at a TCE concentration of 250 ppm_{v/v}. The selection of an interim remediation goal for TCE alone was based on the observation that TCE is the principal subsurface contaminant and contributes approximately 90% of the total baseline risk. Possible cumulative effects from other contaminants will be addressed in the Final ROD for the Building 834 OU.

2.7. Description of Remedial Action Alternatives

The Feasibility Study for the Building 834 OU presented six alternatives to address VOC inhalation risks and to remove subsurface VOCs. Since migration of contaminated soil vapor from the vadose zone beneath the core of the complex may pose a threat to human health, its management and remediation were the focus of the FS. The six remedial action alternatives are summarized in Table 24.

2.7.1. Alternative 1—No Action

A no-action alternative is generally required as a basis from which to develop and evaluate remedial alternatives and is the postulated basis of the baseline risk assessment. Under a no-action response, all remedial activities in the Building 834 Complex would cease. However, the following activities would be performed:

- Installation of ten dedicated shallow soil vapor monitoring points.
- Installation of three additional ground water monitor wells.
- Sealing and abandonment of two existing ground water monitor wells.
- Monitoring, reporting, maintenance, database management, and quality assurance/quality control (QA/QC).

The present-worth cost of Alternative 1 is \$4.19 million, which includes up to 30 years of soil vapor and ground water monitoring.

2.7.2. Alternative 2—Exposure Control

Alternative 2 focuses on 1) minimizing human exposure to inhalation of TCE and other contaminants evaporating from the subsurface, 2) reducing the potential for further contaminant mobilization in soil and ground water caused by infiltrating rain water, and 3) reducing LNAPLs.

Alternative 2 includes:

- All elements of Alternative 1.
- Modification of building ventilation in selected buildings to provide increased circulation. This would reduce the inhalation risk associated with exposure to indoor air.
- Institutional exposure controls to reduce the health risk represented by exposure to VOCs within potential risk areas identified in the SWRI risk assessment. These measures would consist of fences, warning signs, and similar controls on site access and exposure.
- Additional drainage controls, such as asphalt paving, along the perimeter of the Building 834 Complex core area. The objective would be to reduce recharge of water to the perched water-bearing zone.
- LNAPL skimming and disposal to reduce LNAPL mass.

The present-worth cost of Alternative 2 is \$5.69 million. This cost includes up to 2 years of LNAPL recovery and up to 30 years of soil vapor and ground water monitoring.

2.7.3. Alternative 3—Source Mass Removal using SVE

The objective of Alternative 3 is to 1) reduce soil vapor VOC concentrations in the upper 12 ft of the vadose zone to health-risk-based concentrations (250 ppm_{v/v}) associated with a total HI of 1, which corresponds to an excess potential cancer risk of 3×10^{-5} , and 2) reduce LNAPLs. Alternative 3 consists of:

- All elements of Alternative 2.
- The institutional and exposure controls described in Alternatives 1 and 2, including additional ventilation to reduce potential exposure risks due to inhalation of VOC vapors.
- SVE and treatment.

The present-worth cost of Alternative 3 is \$8.72 million. This cost includes up to 2 years of LNAPL recovery, up to 5 years of SVE, and up to 30 years of soil vapor and ground water monitoring.

2.7.4. Alternative 4—Source Mass Removal using SVE and Dewatering

As with Alternative 3, the objective of Alternative 4 is to 1) reduce VOC concentrations in the vadose zone to health-risk-based concentrations associated with a total HI of 1, and 2) reduce LNAPL contaminant mass. The major components of Alternative 4 include:

- All elements of Alternative 3.
- Partial dewatering of the perched water-bearing zone to enhance SVE. Extracted ground water would be treated using an oil/water separator to remove LNAPLs, a low-profile tray (or similar type) air stripper, and a GAC vapor emissions control. Treated ground water effluent would be pumped to an effluent storage tank and later discharged on site through an air misting system to a sloped, undeveloped, grassy area east of the Building 834 Complex.

The present-worth cost of Alternative 4 is \$10.38 million. This includes up to 2 years of LNAPL recovery, up to 5 years of SVE and dewatering, and up to 30 years of soil vapor and ground water monitoring.

2.7.5. Alternative 5—Source Mass Removal Using SVE and Ground Water Plume Control

As with Alternatives 3 and 4, the objective of Alternative 5 is to reduce VOC concentrations in the vadose zone to health risk-based concentrations and reduce LNAPL contaminant mass. Alternative 5 would include all of the elements for Alternative 4 and use additional dewatering at the Building 834 septic tank release area and the W-834-T2 and -T4 well cluster areas to provide downgradient VOC plume control and mass removal. The additional dewatering of the perched water-bearing zone would also reduce the potential for future plume migration by further reducing plume mass and volume, thus being slightly more protective of the environment. The major components of Alternative 5 include:

- All elements of Alternative 4.
- Downgradient ground water extraction for plume migration control.

The present-worth cost of Alternative 5 ranges from \$11.80 million to \$16.45 million depending on the duration of ground water extraction. This includes up to 5 years of SVE, between 5 and 30 years of dewatering (with up to 2 years of LNAPL recovery), up to 20 years of soil vapor monitoring, and up to 30 years of ground water monitoring.

2.7.6. Alternative 6—Interim Source Mass Removal

As with Alternatives 3, 4, and 5, the objective of Alternative 6 is to reduce VOC vapor concentrations in the vadose zone to health-based concentrations associated with a total HI of 1, and reduce LNAPL contaminant masses near the release areas. Alternative 6 also adds DNAPL mass reduction via innovative technologies. The major components of Alternative 6 include:

- All elements of Alternative 4.
- SVE and treatment. Extracted soil vapor will be treated using GAC. The ISVRL goal is a TCE concentration of 250 ppm_{v/v} in subsurface soil vapor. Modeling indicates that this goal will be reached in approximately 5 years.
- Innovative technology development, testing, and application both for enhanced removal of undissolved TCE DNAPL in the vadose and shallow, perched water-bearing zones, and treatment of extracted soil vapor and ground water. The objective will be to identify technologies that shorten cleanup time, improve cleanup efficiency, and reduce cost.

The present-worth cost of the selected alternative is estimated to be approximately \$10.38 million. This assumes up to 2 years of LNAPL recovery, up to 5 years of SVE and dewatering, and up to 30 years of soil vapor and ground water monitoring. These time and cost estimates do not include the development or testing of any innovative technologies.

Because no proven technology is currently available to remediate TCE DNAPL in the subsurface, DOE/LLNL will test innovative technologies, which may include alcohol flooding, surfactants, bioremediation, dual-gas partitioning tracers, *in situ* radio frequency heating, resin adsorption, electron accelerator, and ozone treatment. The application of innovative technologies is extremely important in addressing subsurface DNAPL contamination. Analytical data strongly suggest that a volume of contaminant may be present as DNAPLs in the subsurface, and no DNAPL remediation systems currently exist. Three innovative technologies (alcohol flooding, surfactants, and dual gas partitioning tracers) are directly applicable to characterizing and/or remediating subsurface DNAPLs, and are currently under consideration. Descriptions of these technologies are presented in the FS.

2.8. Summary of Comparative Analysis of Alternatives

We have evaluated the characteristics of the six alternatives with respect to the nine EPA evaluation criteria:

- Overall protection of human health and environment.
- Compliance with ARARs.
- Short-term effectiveness.
- Long-term effectiveness and permanence.
- Reduction of toxicity, mobility, or volume.
- Implementability.
- Cost-effectiveness.
- Regulatory acceptance.
- Community acceptance.

DOE/LLNL and the regulatory agencies agree that Alternative 6 provides the best balance of trade-offs with respect to the evaluation criteria. Community acceptance is discussed in the Responsiveness Summary of this Interim ROD. In the following sections, Alternatives 1

through 6 are compared in relation to the remaining seven criteria. Table 25 summarizes this comparative evaluation with respect to all nine criteria.

2.8.1. Overall Protection of Human Health and the Environment

- Alternative 1 does not actively remediate contaminated soil or ground water, which will not protect human health or the environment.
- Alternative 2 protects human health inside the buildings by providing inhalation exposure controls. However, this alternative would not protect human health and the environment outside of the buildings because it does not remediate contaminated soil vapor or ground water.
- Alternative 3 protects human health and the environment by using SVE to remediate contaminants in the shallow vadose zone and skimming to reduce LNAPL mass.
- Alternative 4 protects human health and the environment by supplementing SVE with dewatering. This method would provide more efficient contaminant removal than Alternative 3 since a greater soil volume will be exposed for SVE by dewatering.
- Alternative 5 supplements SVE and dewatering with more extensive ground water extraction, which would remove more subsurface contaminants more efficiently than Alternative 4. However, this alternative would not be more protective of human health and the environment than Alternatives 4 or 6 since there is no pathway that could result in exposure to contaminants in the perched ground water.
- Alternative 6 (the selected remedy) combines the elements of Alternative 4 with the testing and implementation of innovative technologies for DNAPL remediation. This alternative would be at least as protective to human health and the environment as Alternative 4 and may be more protective of the environment since innovative technologies may prove to be more effective at contaminant mass removal than SVE and dewatering alone.

2.8.2. Compliance with ARARs

Except for Alternative 1 (no action), all alternatives would meet all ARARs for this interim remedial action. DOE/LLNL is currently working with the Central Valley RWQCB to propose an amendment to the Basin Plan to exclude the perched water-bearing zone as a drinking water source because DOE/LLNL believes that the perched water-bearing zone does not meet State criteria with respect to water yield or natural quality (even without contamination). The Basin Plan currently defines the perched water-bearing zone as a potential drinking water source and, therefore, may require remediation of ground water to protect beneficial use. Such a requirement may include remediation to background concentrations depending on technical and economic feasibility. If the RWQCB grants an amendment, less stringent ground water cleanup criteria and soil cleanup criteria to protect ground water may be applied. Ground water remediation goals and soil remediation goals to protect water quality will be presented in the Final ROD for the Building 834 OU.

2.8.3. Short-Term Effectiveness

- Alternative 1 does not remove significant quantities of VOCs from the subsurface. Therefore, this alternative would not be effective in short-term remediation of the site.
- Alternative 2 removes only LNAPLs from the subsurface. Since this alternative does not reduce VOC mass, it would not provide short-term remediation of the site.
- Alternative 3 uses SVE to immediately begin removing VOCs and reducing VOC soil vapor concentrations.

- Alternative 4 combines SVE with dewatering to immediately begin removing VOCs and reducing VOC soil vapor concentrations. Dewatering would allow Alternative 4 to remediate a greater soil volume than Alternative 3.
- Alternative 5 combines the elements of Alternative 4 with more extensive ground water extraction to immediately begin removing VOCs and reducing VOC soil vapor concentrations. This alternative would probably be as effective in the short term as Alternative 4.
- Alternative 6 combines all elements of Alternative 4 with treatability testing of innovative remediation technologies. Innovative technologies may provide the greatest short-term effectiveness by removing higher quantities of contaminants than Alternative 4 or 5.
- All alternatives would be protective of site workers and the community during the remedial action. No adverse environmental impacts are anticipated.

2.8.4. Long-Term Effectiveness and Permanence

- Alternative 1 does not provide long-term effectiveness in meeting ISVRLs by not actively remediating contaminated soil and ground water.
- Alternative 2 removes only LNAPLs from the subsurface. Since this alternative does not reduce VOC mass, it would not provide long-term effectiveness or permanence.
- Alternative 3 uses SVE to provide long-term effectiveness through VOC mass removal and would permanently reduce VOC soil vapor concentrations to ISVRLs.
- Alternative 4 combines SVE with dewatering to remediate a greater soil volume than Alternative 3 and would provide long-term effectiveness and permanence.
- Alternative 5 uses SVE and more extensive ground water extraction to provide long-term effectiveness through mass removal and plume control, which would provide long-term effectiveness and permanence in reducing soil vapor concentrations of VOCs to ISVRLs.
- Alternative 6 combines all elements of Alternative 4 with treatability testing of innovative remediation technologies. Innovative technologies may provide the greatest long-term effectiveness and permanence by removing higher quantities of contaminants than the technologies of Alternative 4 alone and, thus, are also more protective of the environment.

2.8.5. Reduction of Toxicity, Mobility, or Volume

- Alternative 1 does not remove significant quantities of VOCs from the subsurface. Therefore, this alternative would not reduce toxicity, mobility, or volume of the VOCs.
- Alternative 2 removes LNAPLs, but would not remove significant quantities of VOCs from the subsurface. Therefore, this alternative would not reduce the toxicity, mobility, or volume of the VOCs.
- SVE and LNAPL recovery in Alternative 3 would significantly reduce the toxicity, mobility, and volume of contaminants in the subsurface.
- By adding dewatering to SVE and LNAPL recovery, Alternative 4 would reduce the toxicity, mobility, and volume of contaminants in the subsurface more efficiently than Alternative 3.
- SVE, dewatering, plume control, and LNAPL recovery in Alternative 5 would effectively reduce the toxicity, mobility, and volume of contaminants in the subsurface.

- Alternative 6 would supplement the elements of Alternative 4 with innovative technologies, which may reduce the mobility, volume, and mass of VOCs, DNAPLs, and LNAPLs in the vadose zone and saturated zone more effectively than Alternative 4 alone. Because Alternative 6 will likely remove the largest amount of contaminant source mass, it is more protective of the environment and reduces future migration potential.

2.8.6. Implementability

- Alternative 1 can be implemented easily with slight modifications to the existing ground water monitoring program.
- Alternative 2 can be implemented using standard design and construction techniques and materials to modify building ventilation and surface drainage. Passive skimmers for LNAPL recovery are readily available, and DOE/LLNL has facilities to properly handle recovered LNAPLs as hazardous waste.
- The SVE system and surface and drainage modifications of Alternative 3 are readily implementable. Major components of the remediation system are currently in place, and SVE, air stripping, and vapor-phase GAC are commercially available. However, SVE would involve some additional construction and long-term operation of remediation facilities.
- The soil vapor and ground water treatment technologies incorporated into Alternatives 4 and 5 are readily available and many of the major components are already in place. These alternatives would involve some additional construction and long-term operation of remediation facilities in addition to the drainage control and ventilation projects. Phase separation, air stripping, and vapor-phase GAC are commercially available.
- In Alternative 6, the soil vapor and ground water treatment technologies of Alternative 4 are combined with treatability testing of innovative technologies. Although the design of innovative technologies is difficult to predict, DOE/LLNL has the technical resources to implement each possible remedial alternative.

2.8.7. Cost-Effectiveness

- The present-worth cost of Alternative 1 is \$4.19 million for up to 30 years of soil vapor and ground water monitoring. This alternative has the lowest cost because it does not include remedial actions.
- The present-worth cost of Alternative 2 is \$5.69 million. This includes up to 2 years of LNAPL recovery and up to 30 years of soil vapor and ground water monitoring. Alternative 2 has a higher cost because it includes capital construction projects (drainage controls and ventilation retrofits) and ground water monitoring, but no remediation by long-term extraction and treatment.
- The present-worth cost of Alternative 3 is \$8.72 million. This includes up to 2 years of LNAPL recovery, up to 5 years of SVE, and up to 30 years of soil vapor and ground water monitoring. The higher cost of Alternative 3 is due to capital construction projects, as well as ground water monitoring and soil vapor treatment.
- The present-worth cost of Alternative 4 is \$10.38 million. This includes up to 2 years of LNAPL recovery, up to 5 years of SVE and dewatering, and up to 30 years of soil vapor and ground water monitoring. The dewatering and ground water treatment in Alternative 4 adds cost, so estimated total costs for this alternative are greater than for Alternative 3.
- The present-worth cost of Alternative 5 ranges from \$11.80 million to \$16.45 million depending on the duration of ground water extraction. This includes up to 5 years of

SVE, between 5 and 30 years of dewatering, up to 2 years of LNAPL recovery, up to 20 years of soil vapor monitoring, and up to 30 years of ground water monitoring. The estimated total costs of Alternative 5 may be the highest because the duration of ground water extraction could be up to 30 years, compared to 5 years for Alternatives 3 and 4. In addition, this alternative requires a second ground water extraction and treatment system.

- The total estimated cost of Alternative 6 is \$10.38 million. Since costs and effects of innovative technologies are difficult to predict, their costs are not included in this estimate. However, if innovative technologies remove contaminants more efficiently than SVE and dewatering alone, site cleanup goals may be reached sooner and costs may be reduced.

2.9. Selected Remedy

DOE/LLNL, U.S. EPA, RWQCB, and DTSC agree that Alternative 6, which combines the treatability testing of innovative technologies with SVE and partial dewatering, would provide the best balance of trade-offs with respect to the CERCLA evaluation criteria. DOE/LLNL would begin subsurface remediation using SVE with dewatering to reduce potential risk and contaminant mass. During and/or following these actions, innovative remediation technologies would be applied and tested to enhance TCE DNAPL removal, and treatment of extracted soil vapor and/or ground water.

2.9.1. Treatment System Design

The majority of the risk reduction components are readily implementable with minor modifications to the existing soil vapor and ground water extraction and treatment systems at the core area of the Building 834 OU. The risk level for TCE is based on soil vapor exposure outside of Building 834D. The selected remedy targets a 3×10^{-5} cancer risk and an HI of 1 for an ISVRL for TCE of 250 ppm_{v/v}, which corresponds to a soil concentration of 2.2 mg/kg.

The major components of the selected remedy include:

- Installation of additional dedicated soil vapor monitoring points to monitor the progress of remediation.
- Installation of additional ground water monitor wells.
- Sealing and abandonment of several existing ground water monitor wells.
- Modification of ventilation systems in selected buildings to increase air circulation and reduce the inhalation risk from TCE vapors that may be migrating into the building from subsurface soil.
- Institutional exposure controls such as fences, warning signs, and excavation restrictions.
- Surface water drainage controls, such as asphalt paving, to reduce recharge of precipitation to the perched water-bearing zone.
- LNAPL (T-BOS and diesel) extraction and treatment. Extracted LNAPLs in well W-834-D8 will be removed using a passive skimmer. T-BOS from wells W-834-D3, -D4, and -D5 will be actively skimmed using a pneumatic pumping system. All recovered LNAPLs will be removed from the site by a licensed hauler and transported to a facility that has a Resource Conservation and Recovery Act (RCRA) permit for either incineration or recycling.
- SVE and treatment (Fig. 9). DOE/LLNL will upgrade the existing SVE system at the Building 834 Complex to enhance its TCE removal capacity. New wells would be installed to provide additional locations for SVE. The locations of existing and proposed

SVE wells are shown on Figure 4-3 of the FS. Extracted soil vapor will be treated using GAC or other technology. The ISVRL TCE concentration is 250 ppm_{v/v}, and modeling indicates that this goal would be reached in approximately 5 years. The SVE model used to estimate soil vapor cleanup time accounts for all possible phases, including DNAPL. However, it is possible that continuous volatilization of DNAPLs into the vadose zone could lengthen the actual cleanup time. Concentrations of contaminants in soil vapor would be monitored at dedicated soil vapor sampling points and at SVE wells for an agreed-upon period of time. If TCE concentrations increase above an acceptable level, the SVE system will be restarted.

- Partial dewatering of the perched water-bearing zone to enhance the effectiveness of SVE by exposing a larger soil volume to vapor flow. Extracted ground water will be treated by a low-profile type (or similar type) air stripper with GAC emissions control, then discharged through an air misting system (Fig. 10). There is currently no specific cleanup goal for *in-situ* ground water in the perched zone.
- Innovative technology development, both for enhanced removal of subsurface contamination and treatment of extracted soil vapor and ground water. The objective will be to identify technologies that shorten cleanup time, improve cleanup efficiency, and reduce cost. Technologies to be tested may include, but are not limited to, alcohol flooding, surfactants, bioremediation, dual-gas partitioning tracers, *in situ* radio frequency heating, resin adsorption, electron accelerator, and ozone treatment. Three of these innovative technologies (alcohol flooding, surfactants, and dual-gas partitioning tracers) are directly applicable to characterizing and/or remediating subsurface DNAPLs, and are currently under consideration for the Building 834 Complex core area.

The Final ROD for the Building 834 OU will identify the selected remedial technologies. Evaluation criteria will be developed to ensure that remediation is conducted as effectively and rapidly as possible. If monitoring indicates that the tested technology fails to meet the evaluation criteria, DOE/LLNL will meet with the regulatory agencies to discuss the implementation of another remedial alternative. If a tested technology successfully meets the established criteria, that technology will be permanently implemented as soon as possible.

- Table 26 shows the current soil vapor and ground water monitoring program for the Building 834 OU.

2.9.2. Summary of Preliminary Cost Estimates

The 1994 present-worth cost of the selected remedy is estimated to be approximately \$10.38 million as summarized in Table 27. This cost estimate assumes up to 2 years of LNAPL recovery, up to 5 years of SVE and dewatering, and up to 30 years of soil vapor and ground water monitoring. These time and cost estimates do not include the development or testing of innovative technologies. Cost estimates and equipment may change as the result of modifications during the remedial design and construction processes. Cleanup goals and length of cleanup time can be re-evaluated with the regulatory agencies every 5 years, based on the effectiveness of the remediation system, changes in site conditions, and changes in regulatory requirements.

2.10. Statutory Determinations

The selected interim response action for the Building 834 operable unit satisfies the mandates of CERCLA Section 121. The remedy will:

- Protect human health by achieving the inhalation risk RAO for the operable unit.

- Comply with ARARs (or justify an interim waiver).
- Be cost effective.

DOE/LLNL, U.S. EPA, RWQCB, and DTSC believe that among the six proposed remedial alternatives, Alternative 6 provides the best balance of trade-offs with respect to the CERCLA evaluation criteria. Site 300 will remain under the control and ownership of DOE for the foreseeable future. This relationship is a major factor in defining the scope of the remedy proposed in this Interim ROD. A brief description of how the selected remedy satisfies each of these statutory requirements is provided below.

2.10.1. Overall Protection of Human Health and the Environment

Potential elevated health risks result from VOC contamination in vadose zone soil vapor between 0–12 ft beneath the core of the Building 834 Complex. SVE with dewatering and LNAPL recovery will be used during or post-surfactant injection to reduce the volume and toxicity of the contaminants and limit VOC migration. All emissions and ground water will be treated before discharge to the environment. Soil vapor and ground water monitoring will document the progress and permanence of all remediation methods.

Based on the chemicals of concern, exposure routes, potential receptors, and the findings of the baseline risk assessment, the potential excess cancer risk remediation goal for soil vapor is 3×10^{-5} , based on achieving an HI of 1.

Innovative remedial technologies will be implemented and tested at the site. DOE/LLNL plans to begin this effort by testing surfactant injection, which should increase the solubility of DNAPLs and LNAPLs and increase contaminant recovery rates. In addition, protection of human health will be ensured by improving ventilation in Buildings 834A, D, J, and O, and restricting site construction and access. Surface drainage improvements in the Building 834 Complex area will reduce infiltration and subsequent migration of contaminants from the source areas.

In accordance with a DOE Secretarial Policy issued in June 1994, NEPA values contained in the Environmental Considerations chapter of the FS satisfy the requirements for CERCLA-NEPA integration. As part of these requirements, we evaluated the potential impacts on the existing on- and off-site environment due to implementation of the remedial alternatives. No significant adverse impacts due to implementation of the alternatives were identified.

2.10.2. Compliance with ARARs

Federal and state chemical-, location-, and action-specific ARARs affecting the selected interim remedy are described in Table 28. The selected remedy meets all ARARs. DOE/LLNL is currently working with the Central Valley RWQCB to propose an amendment to the Basin Plan to exclude the perched water-bearing zone as a drinking water source because it does not meet State criteria with respect to water yield or natural quality (even without contamination). The Basin Plan currently defines the perched water-bearing zone as a potential drinking water source and, therefore, may require remediation of ground water to protect beneficial use. Such a requirement may include remediation to background concentrations depending on technical and economic feasibility. If the RWQCB grants the amendment, less stringent ground water cleanup criteria may be applied. Ground water remediation goals will be presented in the Final ROD for the Building 834 OU.

2.10.3. Utilization of Permanent Solutions and Alternative Treatment Technologies

The selected remedy provides long-term effectiveness through mass removal, which will reduce VOC soil vapor concentrations to ISVRLs and acceptable health risk levels. The selected remedy will test, implement, and evaluate promising innovative remedial technologies aimed at DNAPL removal and extracted water and vapor treatment to the fullest extent practicable.

2.10.4. Reduction of Toxicity, Mobility, or Volume as a Principal Element

Contaminant toxicity, mobility, and volume in the soil and ground water will be reduced irreversibly by SVE, dewatering, and LNAPL recovery. Innovative technologies may significantly reduce the toxicity, mobility, and volume of DNAPLs in the subsurface, enhance the progress of VOC removal, and be more protective of the environment. SVE and dewatering will reduce the volume and concentration of contaminants in the subsurface; however, without DNAPL removal, subsurface concentrations of TCE could rebound after SVE is discontinued.

2.10.5. Cost Effectiveness

DOE/LLNL, U.S. EPA, RWQCB, and DTSC agree that Alternative 6 is the best value since this remedial alternative provides the opportunity to test and implement innovative technologies that may prove to be more efficient and cost-effective than the currently available technologies. Each alternative was costed on the basis of a design to reduce inhalation risks and provide source mass removal of contaminants, to prevent emissions of VOCs to the air, and to treat waste water to a TCE concentration $<0.5 \mu\text{g/L}$ (Fig. 11).

3. Responsiveness Summary

This section responds to public comments directed to DOE, LLNL, U.S. EPA, and the State of California regarding the Proposed Plan (PP) for the remediation of the Building 834 Operable Unit (OU). Responses to community comments and concerns are incorporated into this Interim ROD.

The public comment period on the PP began January 9, 1995, and ended February 9, 1995. On January 24, 1995, DOE/LLNL and the regulatory agencies held a public meeting at the Tracy Inn in Tracy, California to present the proposed remediation plan and allow the public to ask questions and comment on the preferred remedial alternative. After representatives from LLNL summarized the information presented in PP members of the public directed questions to a panel of DOE, LLNL, and regulatory agency representatives. Following the question-and-answer session, three members of the public read their concerns into the formal public record. Although no letters were received during the PP comment period, members of the Tri-Valley Citizens Against a Radioactive Environment (CAREs) provided a written record of their meeting comments and additional comments that were not presented at the meeting. The meeting transcript and a copy of the written concerns are available to the public at the LLNL Visitors Center and the Tracy Public Library.

3.1. Organization of the Responsiveness Summary

The Responsiveness Summary is organized to clearly present the breadth of public concerns while avoiding repetition. In keeping with EPA Superfund guidance and common accepted practice, comments are grouped by subject. If two or more comments are identical or similar, only one response is provided. Whenever possible, comments are summarized verbatim from either the meeting transcript or written comments.

Public comments are grouped into the following sections:

- Selected Remedial Action.
- Protection of the Environment.
- Impact of Future Activities.
- Community Relations.
- General Comments.

3.2. Summary of Public Comments and Responses

3.2.1. Selected Remedial Action

Comment 1:

One of the things that needs to be stated clearly and unequivocally is that the levels of contamination both at Building 834 area and Site 300 in general are extremely high. I've worked in monitoring cleanups at other facilities and these, you know, numbers like 800,000 parts per billion TCE. I mean, that's not a number you see very often. And the tritium peaking at eight hundred thousand picocuries per liter with current concentrations of a least 300 thousand picocuries per liter. So this is a very serious cleanup even though the area is more remote, say, than the main site. The contaminant levels are themselves a concern. At that level,

we suspect that there is probably free product sinking in terms of the TCE contamination that will complicate the cleanup. That needs to be considered.

Response 1:

Remediation of the perched water-bearing zone and standards for ground water cleanup will be discussed in the Final ROD. Although the perched ground water contains VOCs, this ground water does not pose a risk to human health or the environment because there are no exposure pathways. Since migration of contaminated soil vapor from the vadose zone beneath the core of the Building 834 Complex may pose a threat to human health, monitoring, management, and remediation are the purposes of the selected interim remedial action.

DOE/LLNL and the regulatory agencies agree that the selected interim remediation decisions made for this site will mitigate the potential human health inhalation risk associated with the Building 834 OU. We agree that TCE as free product probably exists as residual DNAPL in the subsurface. This is a primary driver for the inclusion of innovative technologies in the selected remedy. The high concentrations of VOCs in ground water will be addressed in the Final ROD. No cleanup goals for ground water are presented in this Interim ROD.

There was no tritium used, nor has any tritium contamination been detected, in the Building 834 OU.

Comment: 2

The cleanup standard chosen for Volatile Organic Compounds in soil (2.2 mg/kg or 250 ppm_{v/v} in soil vapor) appears to be set too high. We note that in the South Bay, industry is asking for a standard of 0.5 mg/kg. Moreover, the cleanup standard assumes an occupational standard in industrial use of Building 834. While this assumption may be reasonable in the short term, given the uncertainties of funding for Lab activities, we believe a more conservative standard should be analyzed. Our position is supported by EPA OSWER Directive 9355.0-30, Role of the Baseline Risk Assessment in Superfund Remedy Selection Decision, April 1991. On page 5, EPA states, "both current and reasonable future risks need to be considered..." based on an assumption of future land use different from that which currently exists. The potential land use "associated with the highest level of exposure and risk..." should be used in developing remediation objectives. Further, the National Contingency Plan states that EPA will consider future land use as residential in many cases, "and undeveloped areas can be assumed to be residential in the future unless sites are in areas where residential land use is unreasonable."

We do not believe that LLNL has made any showing that future residential land use either upon or abutting Site 300 is an unreasonable scenario. Therefore, if the assumption concerning reasonable land use yields a stricter cleanup standard, we want the Lab to commit to this stricter standard, should land use assumptions change.

Response 2:

The ISVRL was developed by modeling potential TCE vapor inhalation risks. The concentration of TCE in subsurface soil associated with this ISVRL is an HI of 1 and a potential excess lifetime cancer risk of 3×10^{-5} . The regulatory agencies concur with this ISVRL cleanup goal.

These standards do not address the potential for soil vapor to contaminate ground water. However, the TCE concentrations in perched ground water exceed the level that could be caused by soil vapor contamination alone. Given the concentration of VOCs in ground water, VOCs could volatilize into the vadose zone.

DOE is committed to maintaining stewardship of LLNL Site 300 for the foreseeable future, and plans to continue operations at the site in support of national security programs and other

activities of national interest. In so doing, Site 300 and the Building 834 OU will remain inaccessible to the public by the use of security fences and protective surveillance.

The maintenance and mission of Site 300 depend on Congressional funding decisions. If the U.S. Congress decides to terminate or modify operations at Site 300, DOE (or its successor agency, if appropriate) would manage an orderly shutdown of the facility, which would include a reassessment of cleanup standards. The Interim ROD would be modified to reflect changes in land use that could potentially affect site remediation.

Comment 3:

We are deeply concerned that there is no ground water standard for the perched aquifer. While we understand that the Lab is applying for a variance from the State classification as a potential drinking water source, we believe that the ground water should be cleaned up at least to the Maximum Contaminant Level or to a standard which will not incur an Incremental Lifetime Cancer Risk higher than one in a million. The documentation which clearly lays out how this standard will be met should be identified. In this context, we note that there is some evidence the perched aquifer may have been much larger in the past. It is at least possible the "mystery" source of contamination in the Building 833 area could have been the perched aquifer. So we have concerns regarding the Lab's request to delist this aquifer from State waters.

Response 3:

As stated in Response 1, remediation of the perched water-bearing zone will be addressed in the Final ROD. Although the perched ground water contains VOCs, this ground water does not pose a risk to human health or the environment because there are no exposure pathways. Because migration of contaminated soil vapor from the vadose zone beneath the core of the Building 834 Complex may pose a potential threat to human health, the selected interim remedial action has been formulated to monitor, manage, and remediate the contamination.

Under the current Basin Plan, the Central Valley RWQCB considers the perched water-bearing zone a potential drinking water source, a potential receptor, and a possible source and pathway for contaminants to reach the regional aquifer. However, DOE/LLNL is presently working with the Central Valley RWQCB staff to propose an amendment to the Basin Plan to exclude the perched water-bearing zone as a drinking water source. DOE/LLNL believe the existing field and analytical data indicate that the perched water-bearing zone does not meet criteria contained in State Water Resources Control Board Resolution 88-63 (Sources of Drinking Water Policy) with respect to water yield or natural quality (even without contamination). They further believe that the perched water-bearing zone does not provide a pathway for contaminants to reach the regional aquifer. In addition, DOE/LLNL believe that existing hydraulic and analytical data provide significant evidence of the impermeable nature of the perching horizon and the lack of hydraulic communication with the regional aquifer. They will include this information in the proposed amendment.

The Basin Plan currently defines the perched water-bearing zone as a potential drinking water source and, therefore, may require remediation to protect beneficial use. Such a requirement may include remediation to background concentrations or to MCLs, if it is technically or economically infeasible to achieve background concentrations. If the RWQCB grants the amendment, less stringent *in-situ* ground water cleanup criteria may be applied, but additional ground water remedial actions, including but not limited to additional soil source control, will still need to be considered. Cleanup goals for the perched ground water-bearing zone will be developed and presented in the Final ROD.

Comment 4:

That plume, as you may recall from the presentation this evening, 1,500 feet long, about 500 feet wide, as I recall, of the perched water -- and supposedly it sits on top of this clay, impervious clay, which we might conclude as, well, why not just let it sit there and do nothing about it? We feel that this is important to continue that procedure of getting rid of that water.

Response 4:

Because ground water cleanup standards have not yet been established, remediation of the perched water-bearing zone will be addressed in the Final ROD. However, the interim action includes dewatering, which will remove and treat significant amounts of perched ground water.

Comment 5:

Referring to p. 1-18 and p. 1-21 (of the FS), please explain what appears to be incongruous findings: first, that it is estimated that 540 gallons of TCE was released in the vicinity of Building 834 over 16 years; and, second, that there were recent TCE concentrations in ground water up to 800,000 µg/L (ppb).

Response 5:

Historical information and analytical data presented in the SWRI and FS indicate that approximately 550 gallons of VOCs, primarily TCE, were released at ten locations at the Building 834 Complex between the early 1960s and early-1980s. Some of the VOCs eventually migrated to the perched water-bearing zone, which caused the ground water to contain TCE concentrations as high as 800,000 ppb. The estimated volume of TCE spilled is consistent with TCE concentrations in ground water.

The volume of TCE in soil was estimated to be 270 gallons for the soil vapor modeling presented in Appendix F of the *Final Feasibility Study (FS) for the Building 834 Operable Unit* (Landgraf et al., 1994). Mass estimates of TCE in ground water are approximately 800 lb (roughly 70 gallons). These estimates are uncertain due to the undocumented volume of VOCs released, significant subsurface lithologic heterogeneity, limited soil analytical data, variable saturated thickness, and variable VOC concentrations in ground water and soil. As such, these estimates are subject to change with additional information.

Comment 6:

Before the plan is approved (e.g. by the community) it is important the monitoring plan be specified (e.g. number of wells, depth of wells, frequency of sampling, duration of sampling, location of wells etc.) and a contingency plan be specified which delineates what the Lab is committed to do in the event it finds the plume is moving, or is not being remediated in the time-frame or to the extent expected.

Response 6:

A preliminary monitoring plan was presented in the FS primarily to support cost estimates for each remedial alternative. Consistent with the procedures at other U.S. EPA Superfund sites, the monitoring program will be presented in the Remedial Design/Remedial Action documents.

Because the selected remedy results in contamination remaining on site (i.e., not immediately remediated or removed), the agencies are required to review the progress of remediation at least every 5 years to ensure that the selected remedy is effective and continues to adequately protect human health and the environment. Progress of site cleanup will be published in periodic progress reports. If monitoring data indicate that the selected remedy is not effectively remediating the site, DOE/LLNL and the regulatory agencies will discuss implementing another remedial alternative.

Comment 7:

The Feasibility Study (FS) and/or subsequent primary documents should contain milestones by which the success of the remediation can be evaluated. The remedy and accompanying plan should contain firm commitments. It is important to community acceptance that the FS and subsequent plans contain a measurable schedule and performance standards which can be verified. Commitments as to the timing of cleanup activities can and should be spelled out.

Further, we recommend two sets of milestones be codified: contaminant milestones and mass removal milestones. Contaminant milestones would require the Department of Energy and the Lab to set timed goals for incrementally reducing the concentration of VOCs in soil and ground water. Mass removal milestones would the removal of a specified volume of contamination during a specified time period. Five year goals should be spelled out in the Interim ROD and/or other appropriate document(s).

Response 7:

Consistent with U.S. EPA Superfund site procedures and as specified by the CERCLA process, schedules and performance milestones will be presented in design documents.

Every 5 years, the regulatory agencies will review the progress of remediation to ensure that the remedy is effective and continues to provide adequate protection of human health and the environment. Reports on the site cleanup will be published.

If the selected remedy fails to meet the criteria set forth in the design documents, DOE/LLNL and the regulatory agencies will discuss implementing another remedial alternative.

Comment 8:

With regard to the Building 834 complex, the problems there that we have in soil and groundwater are not unique to Californians. It's in the Silicon Valley. It's everywhere. We got chlorinated solvents in soil and ground water. Big problem.

What is unique about the Building 834 complex is we got this little perched aquifer up on a hilltop isolated from the regional aquifer, at [a 280 foot] separation. This has created an opportunity for the Department of Energy. There's letters from the State Water Resources Control Board which support the Lawrence Livermore and DOE to proceed with testing innovative technologies for the remediation of solvents, free-phase solvents (DNAPLs).

It gives us an opportunity to test and search out technologies which will, if proven, will go into other areas like Silicon Valley, wherever we have these big spills, and accelerate those cleanup efforts.

So I just wanted to get it on the record here that I think that the Regional Board has come out in support of the innovative technology approach to the 834 complex. I know that the State Water Resources Control Board has come out in support of that concept.

Response 8:

DOE/LLNL, U.S. EPA, RWQCB, and DTSC agree that the development, testing, and evaluation of innovative technologies have several advantages. Innovative technology testing at Building 834 may expedite remediation, and the successful new technologies could be valuable to other sites, especially where public exposure risks are a greater issue.

Comment 9:

Criteria should be established by which to judge whether to go ahead with an innovative technology after a treatability study. That criteria should be set forth in the FS, and/or other appropriate documents, in case a new technology has only partial success.

Response 9:

Criteria for evaluating a remedial alternative will be established during the treatability study for each technology being tested.

The effectiveness of new technologies will only be known after the technologies have been implemented in the field and their effects are monitored. The remedy selected will be optimized as monitoring data warrants, to make sure that the remediation is conducted as effectively and quickly as possible.

Comment 10:

Referring to Appendix E (of the FS), discussion of resin adsorption-regeneration—although this technology has theoretical advantages for treating off-gas from soil vapor extraction, tests of the Purus Padre system at McClellan AFB have been disappointing. The Air Force is thinking of retesting an improved version at AF Plant 44 in Tucson, Arizona. I strongly recommend that the Lab investigate the McClellan results (contact Bud Hoda) before it invests in this technology.

Response 10:

LLNL's initial efforts to reach Bud Hoda were unsuccessful. However, LLNL has already investigated resin-adsorption regeneration and believes that it is an appropriate and effective technology. If DOE/LLNL proposes to apply this remedial technology at Building 834, LLNL will carefully review its application at other sites and modify the system, if necessary, to optimize its effectiveness.

3.2.2. Protection of the Environment**Comment 11:**

We are concerned that there is not sufficient information to state with certainty that the regional aquifer has not been contaminated.

Response 11:

Since studies began at the Building 834 Complex in 1982, 13 exploratory boreholes have been drilled, and 48 ground water monitoring wells have been installed. Hydraulic tests have been performed on wells in the Building 834 Complex to determine the hydraulic characteristics of the hydrologic units and to define hydrostratigraphic relationships. For example, neutron logging of several deep monitor wells has indicated that the 280 ft of bedrock between the perched zone and the regional aquifer is unsaturated. The results of these tests are summarized in the FS.

DOE/LLNL, U.S. EPA, RWQCB, and DTSC agree that information gathered during site investigations supports the conclusion that the TCE plume in the perched water-bearing zone has not contaminated the regional aquifer.

However, if high concentrations of contaminants are to remain in the perched water-bearing zone, evidence of the impermeable nature of the perching horizon and lack of hydraulic communication with the regional aquifer will need to be cited in the proposed Basin Plan Amendment. Remediation decisions regarding the perched ground water will be included in the Final ROD to the Building 834 OU.

Comment 12:

Referring to page EX-5, please explain in detail how the results of this FS do not have adverse effects in the context of NEPA. Opportunities for on-site and nearby off-site activities

will be foreclosed by adoption of the proposed cleanup standard (based on industrial use scenario).

Response 12:

The purpose of the FS was to develop and evaluate alternatives for remedial action at the Building 834 OU in accordance with CERCLA/SARA and the National Environmental Policy Act (NEPA). Specifically, Chapter 6 of the Building 834 FS provides a detailed NEPA evaluation of potential impacts on the existing on-site and off-site environment due to implementation of the remedial alternative. No significant adverse impacts due to implementation of the alternatives were identified.

Comment 13:

In many Superfund cleanups, a principal is established that does not permit drawing contaminated ground water through less contaminated soil or ground water. We recommend this principal be adopted at Site 300.

Response 13:

The selected remedy does not involve drawing contaminated ground water through less contaminated soil or ground water. We agree that the principal mentioned in the comment is sound practice.

3.2.3. Impact of Future Activities

Comment 14:

We are concerned about the potential for additional contamination stemming from some current and future activities proposed at LLNL's Site 300, such as:

- *Increased hydrotesting activities (implosion of bomb cores using surrogates for plutonium such as uranium 238, and possibly involving tritium as well)*
- *Increased high explosives manufacturing activities*
- *The possibility that Site 300 will be chosen as the nuclear weapons complex's mixed waste dump site.*

Response 14:

These issues are beyond the scope of remediation at the Building 834 OU.

Comment 15:

It is reasonable to assume that Building 834, and/or its associated buildings, will be demolished at some future date (perhaps to be replaced by an industrial building). We would like to see included in the risk-based standard such factors as demolition, disposal of soil and demolition debris, and the effects of soil/vapor exposure on demolition and construction workers.

Response 15:

If LLNL decides to demolish buildings at the Building 834 complex, the risks associated with demolition, disposal of soil and demolition debris, and the effects of soil/vapor exposure on demolition and construction workers will be evaluated. After completing a risk assessment, a site safety plan would be written that would summarize site hazards and establish the levels of personal protective equipment required for demolition and construction workers. LLNL's decommissioning and decontamination activities take place under strict operating procedures which ensure that soil and building debris will be decontaminated and disposed of properly.

3.2.4. Community Relations

Comment 16:

We, the public, have the right to monitor the cleanup. The environment does not belong to the Department of Energy. It belongs to us and our children for seven generations into the future.

Response 16:

DOE/LLNL is committed to providing opportunities for community involvement in the project. The community will be able to monitor and participate in the cleanup process.

Comment 17:

I think we're concerned because there has been a tendency to discount or to indicate to the public that there is no need to be concerned. So many times yet we know that there has -- and this is -- in many cases, there's a difference of opinion among qualified scientific authorities, whether a low level of radiation, for example, is a hazard or not.

Response 17:

Cleanup standards for the Building 834 OU will be based on the best available scientific data, and will meet or exceed environmental and public protection standards. The 250 ppm_{v/v} ISVRL was developed by modeling potential TCE vapor inhalation risk. This vapor concentration correlates to a soil concentration of 2.2 mg/kg and an HI of 1. The regulatory agencies concur with the ISVRL.

We have no evidence that radioactive materials have been released to the environment at the Building 834 OU.

3.2.5. General Comments**Comment 18:**

Tri-Valley CAREs has three over-arching goals in terms of monitoring and participating in decision making in the Site 300 cleanup.

One is to ensure the most thorough cleanup possible. Secondly, to ensure that the technologies that are chosen to clean up the site are themselves protective of human health and the environment. And third to facilitate public involvement in decision making in all aspects of the cleanup.

I really appreciate over the last couple of weeks that the Laboratory has done briefings for our organization. We recently received the technical assistance grant to help get us up to speed quickly on this aspect of the cleanup, and a public meeting was coming down the pipe almost immediately.

And it is unfortunate that this public meeting is not only the same day as the State of the Union address, but also the same day as the public meeting 15 miles away on another laboratory matter which is also important to the public. I do understand that you folks chose the date first, and I will put that on the record.

Response 18:

Comments noted.

Comment 19:

The Department of Energy must commit in writing to provide adequate, stable, long-term funding for this cleanup.

Parenthetically, because the Lawrence Livermore Lab is a Department of Energy facility, cleanup funds must come directly from the Department of Energy, not the Environmental Protection Agency's Superfund account. The Department of Energy has a history of moving money from its cleanup accounts into its weapons programs.

Response 19:

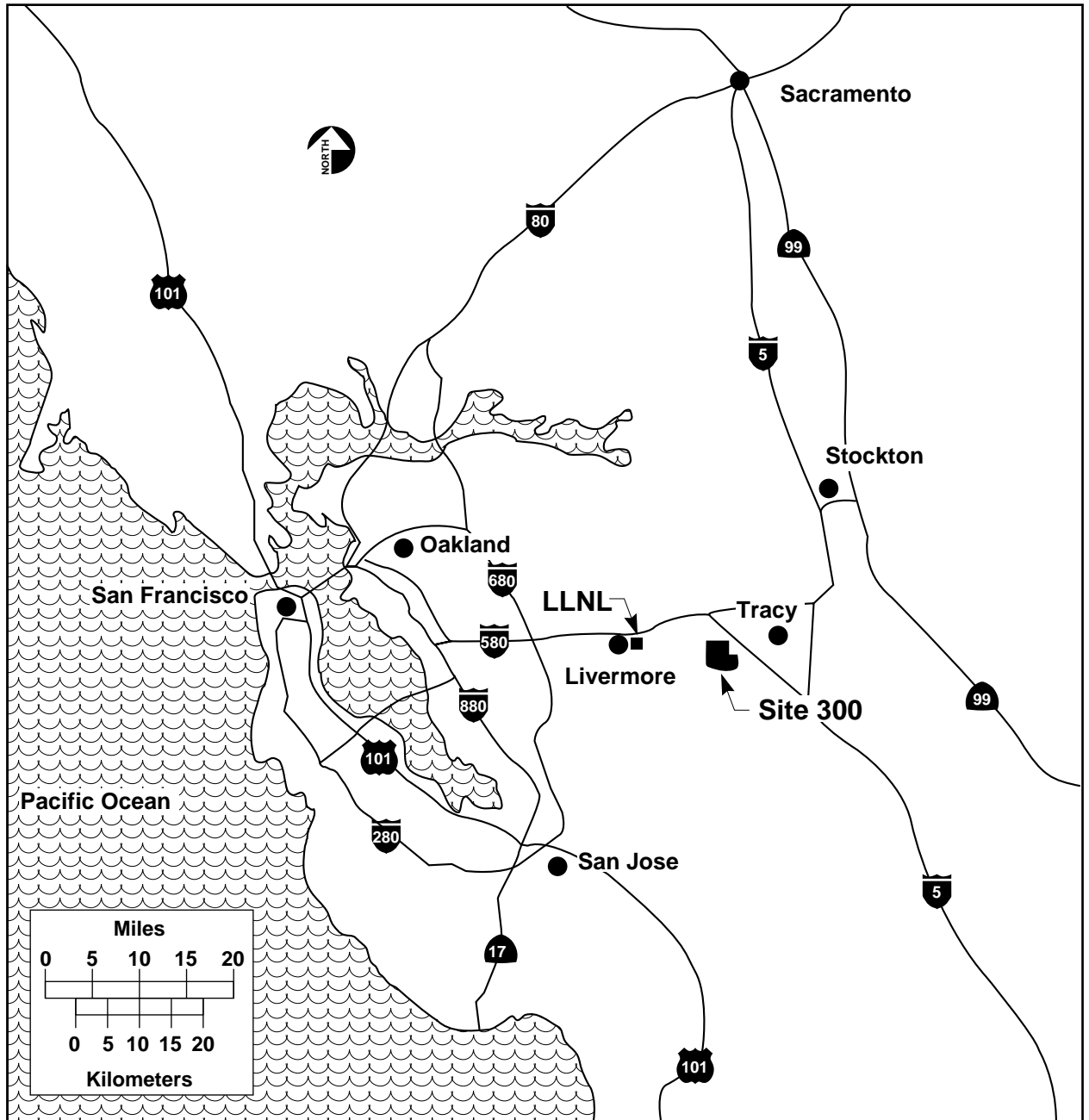
DOE cannot legally commit to funding cleanup or any other activities beyond the current budget year appropriation. However, DOE places a high priority on risk reduction, compliance, and associated contamination cleanup in its annual budget submittals. DOE understands that cleanup delays will likely increase the overall cost of the cleanup at LLNL as well as other facilities, so it is in DOE's best interest to support an adequately funded and progressive cleanup effort through its annual Congressional budget request each year. DOE does commit to request from Congress through the Office of Management and Budget funding necessary to control and remediate contaminant plumes, both on and off site. In addition, DOE is also committed to removing contaminants as efficiently as possible using available technologies within budgeting allocations.

DOE is not currently authorized to establish special funds for specific projects such as environmental restoration. The comment is correct that cleanup funds for the Building 834 OU are from DOE, not the Superfund account. Congress is the only government body that can approve reprogramming and appropriation transfers between weapons design, production, and testing work (as well as other program work) and environmental restoration work. If such a transfer should occur, it is DOE's responsibility to ensure that compliance with environmental regulations is maintained, or that funding be reallocated within available funds, or to request supplemental funding from Congress, if necessary.

References

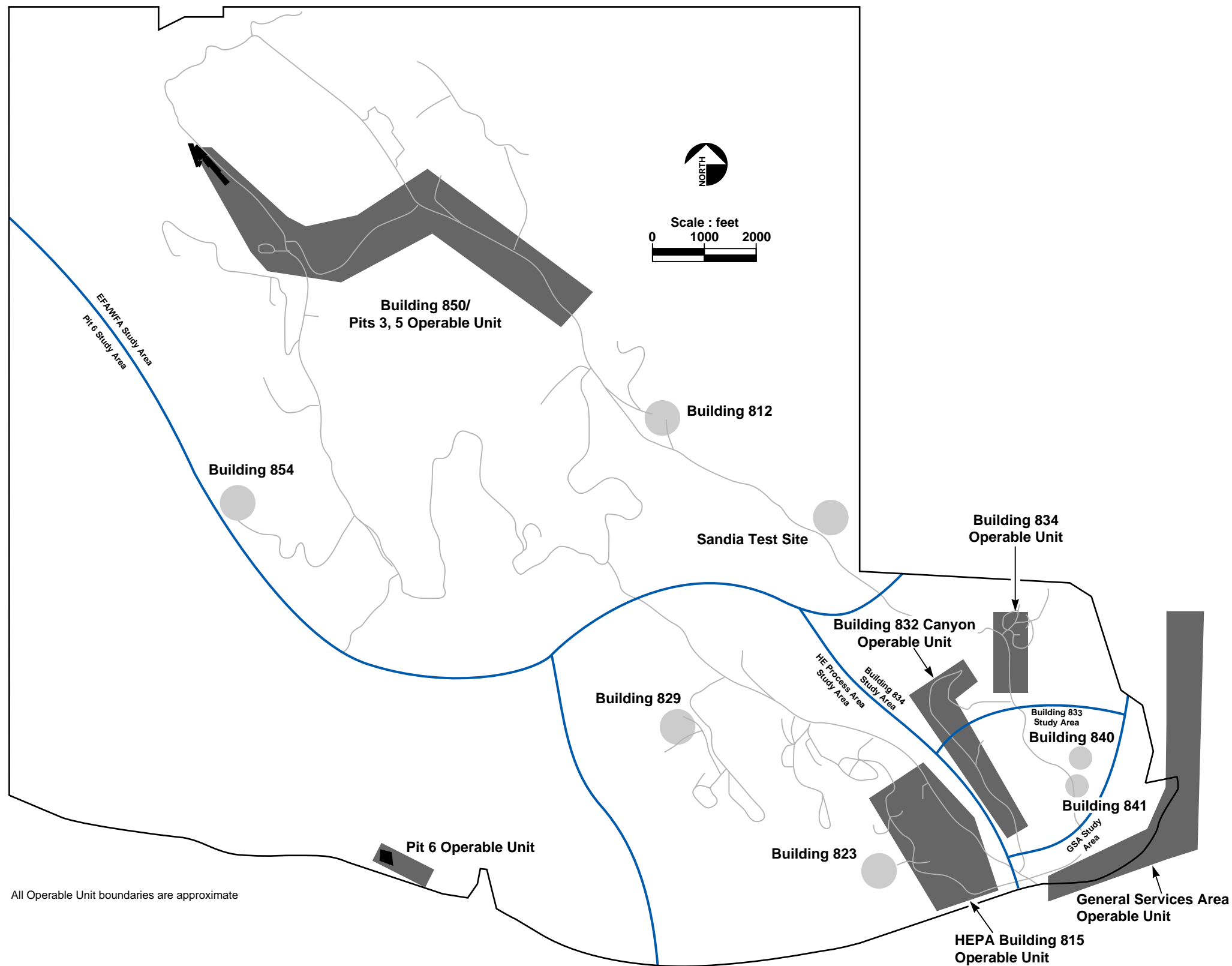
- Anspaugh, L. R., J. H. Shinn, P. L. Phelps, and N. C. Kennedy (1975), “*Resuspension and Redistribution of Plutonium in Soils*,” *Health Phys.* **29**.
- California Environmental Protection Agency (Cal-EPA) (1992) memorandum from Standards and Criteria Work Group to California EPA Departments, Boards, and Offices regarding California Cancer Potency Factors, June 18.
- Hwang, S. T., J. W. Falco, and C. H. Nauman (1986), *Development of Advisory Levels for Polychlorinated Biphenyls (PCBs) Cleanup*, Office of Health and Environmental Assessment, Exposure Assessment Group, U.S. Environmental Protection Agency, Washington, D.C. (PB86-232774).
- In-Situ, Inc. (1986), *PLUME Contaminant Migration*, Laramie, Wyoming (ISI-PLM-2.1-1).
- Landgraf, R., E. Miner, and T. Berry (1994), *Final Feasibility Study for the Building 834 Operable Unit Lawrence Livermore National Laboratory Site 300*, Lawrence Livermore National Laboratory, Livermore, Calif. (UCRL-AR-113863).
- Matthews, S. M., A. J. Boegel, D. W. Camp, A. Caufield, J. O. Cunningham, P. F. Daley, J. J. Greci, M. C. Jovanovich, J. A. Loftis, and P. D. Soran (1992), “Remediation of a TCE Ground Spill Using an Electron Accelerator,” *Proceedings, Nuclear and Hazardous Waste Management, Spectrum ‘92*, August 23–27, 1992, Boise, Idaho.
- McKone, T. E. (1992), Environmental Engineer, Lawrence Livermore National Laboratory, Livermore, California., personal communication with Linda Hall.
- U.S. EPA (1989a), *Risk Assessment Guidance for Superfund, Vol. I: Human Health Evaluation Manual, Interim Final*, Office of Emergency and Remedial Response, U.S. Environmental Protection Agency, Washington, D.C. (EPA/540/1-89/002).
- U.S. EPA (1989b), *Risk Assessment Guidance for Superfund, Vol. II: Environmental Evaluation Manual, Interim Final*, Office of Emergency and Remedial Response, U.S. Environmental Protection Agency, Washington, D.C. (EPA/540/1-89/001).
- U.S. EPA (1990a), *Exposure Factors Handbook*, Office of Health and Environmental Assessment, U.S. Environmental Protection Agency, Washington, D.C. (EPA 600-8-89-043).
- U.S. EPA (1990b), “National Oil and Hazardous Substances Pollution Contingency Plan, Final Rule,” U.S. Environmental Protection Agency, Washington, D.C. (40 CFR Part 300), *Fed. Regist.* **55**(46), pp. 8666–8865.
- U.S. EPA (1991a), *Risk Assessment Guidance for Superfund, Vol. I: Human Health Evaluation Manual, Supplemental Guidance—“Standard Default Exposure Factors,”* Interim Final, Office of Emergency and Remedial Response, Toxics Integration Branch, U.S. Environmental Protection Agency, Washington, D.C. (OSWER Directive: 9285.6–03).

- U.S. EPA (1991b), *Risk Assessment Guidance for Superfund, Vol. I: Human Health Evaluation Manual, (Part B, Development of Risk-based Preliminary Remediation Goals) Interim*, Office of Emergency and Remedial Response, U.S. Environmental Protection Agency, Washington, D.C. (OSWER Directive: 9285.7-01B).
- U.S. EPA (1992a), *Dermal Exposure Assessment: Principles and Applications*, Interim Report, Exposure Assessment Group, U.S. Environmental Protection Agency, Washington, D.C. (EPA/600/8-91/011B).
- U.S. EPA (1992b), *Health Effects Assessment Summary Tables, FY-1992 Annual*, Office of Research and Development, Office of Emergency and Remedial Response, U.S. Environmental Protection Agency, Washington, D.C. (OHEA ECAO-CIN-821).
- U.S. EPA (1992c), *Health Effects Summary Tables*, Supplement No. 2 to the March 1992 Annual Update, Office of Research and Development, Office of Emergency and Remedial Response, U.S. Environmental Protection Agency, Washington, D.C. (OERR 9200.6-303 (92-3)).
- U.S. EPA (1992d), *Integrated Risk Information System—IRIS*, an electronic database maintained by the U.S. Environmental Protection Agency, Office of Research and Development, Environmental Criteria and Assessment Office, Cincinnati, Ohio.
- U.S. EPA (1993), memorandum from D. Stralka, Ph.D., U.S. Environmental Protection Agency, Region IX, to L. Tan, Remedial Project Manager, U.S. Environmental Protection Agency, Region IX, regarding a “Technical request from Linda Hall at Lawrence Livermore National Lab” for toxicity values for PCE, TCE, and tetrahydrofuran, February 25.
- U.S. EPA (1994), memorandum from Stanford J. Smucker, Technical Support Section of U.S. EPA regarding Region IX Preliminary Remediation Goals (PRGs) Second Half 1994, August 1.
- Webster-Scholten, C. P., Ed. (1994), *Final Site-Wide Remedial Investigation Report, Lawrence Livermore National Laboratory Site 300*, Lawrence Livermore National Laboratory, Livermore, Calif. (UCRL-AR-21010).



ERD-ROD-834-3319

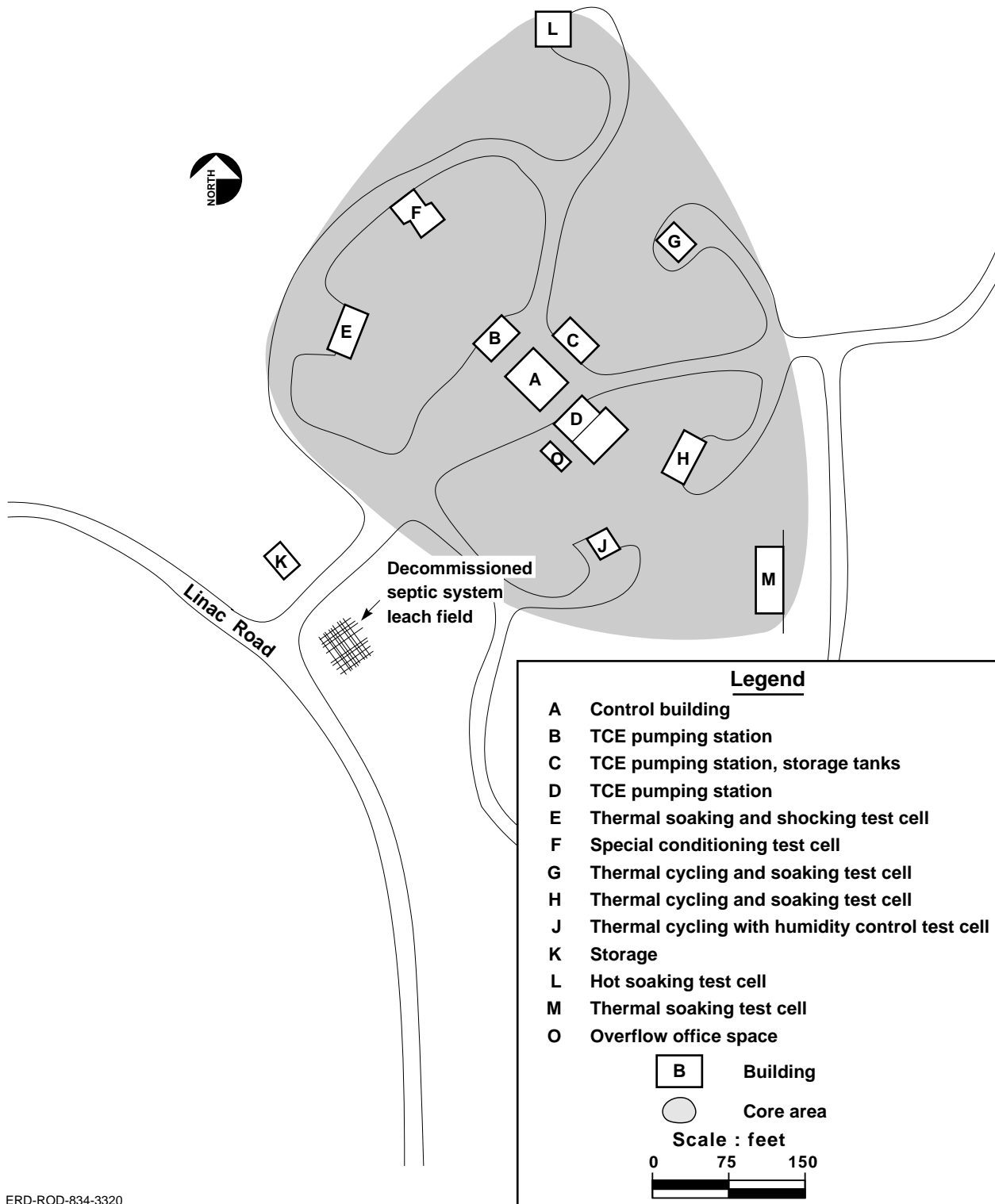
Figure 1. Locations of LLNL Main Site and Site 300.



All Operable Unit boundaries are approximate

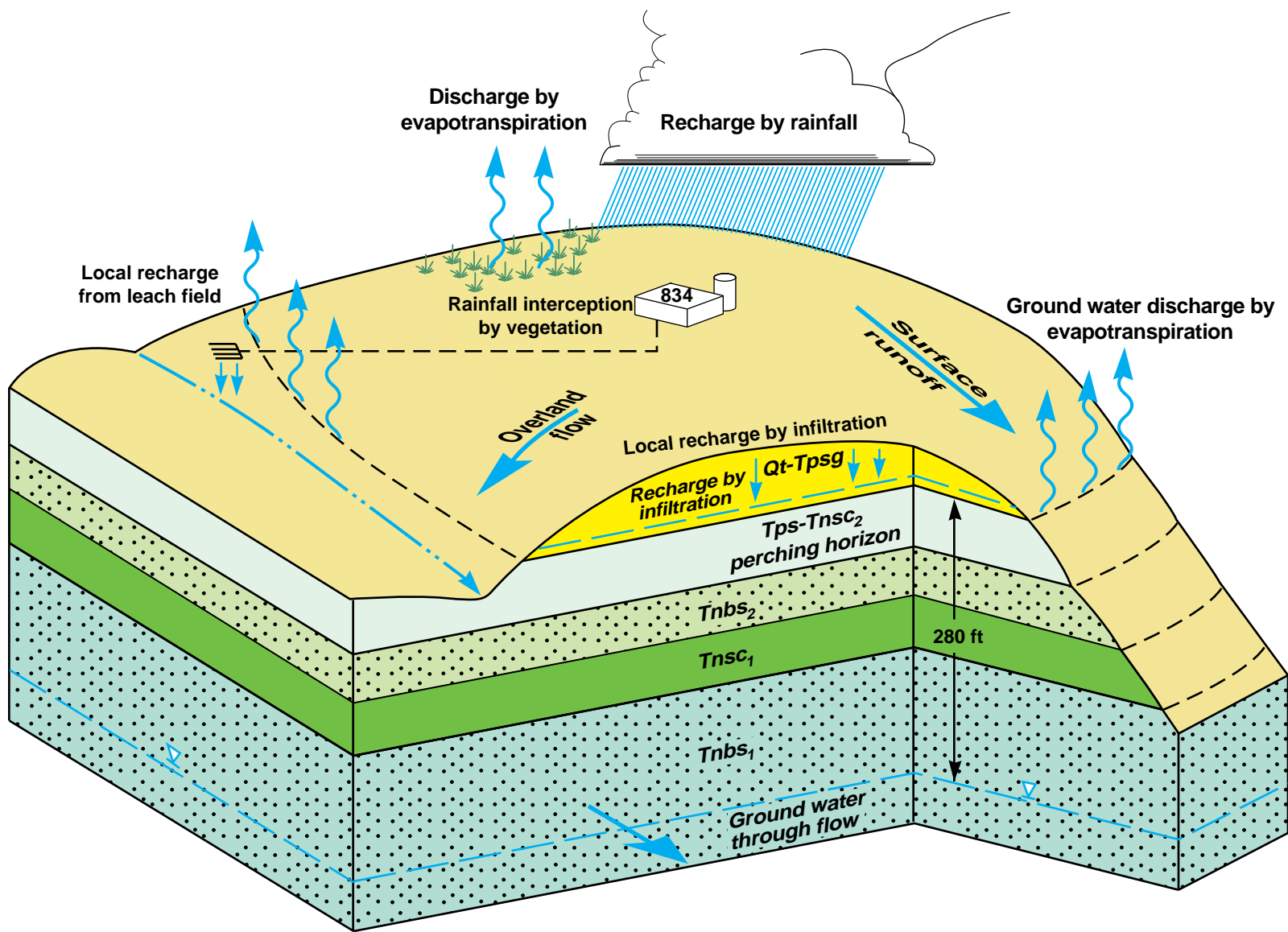
ERD-ROD-834-3329

Figure 2. Operable Units and SWRI Study Areas at LLNL Site 300.



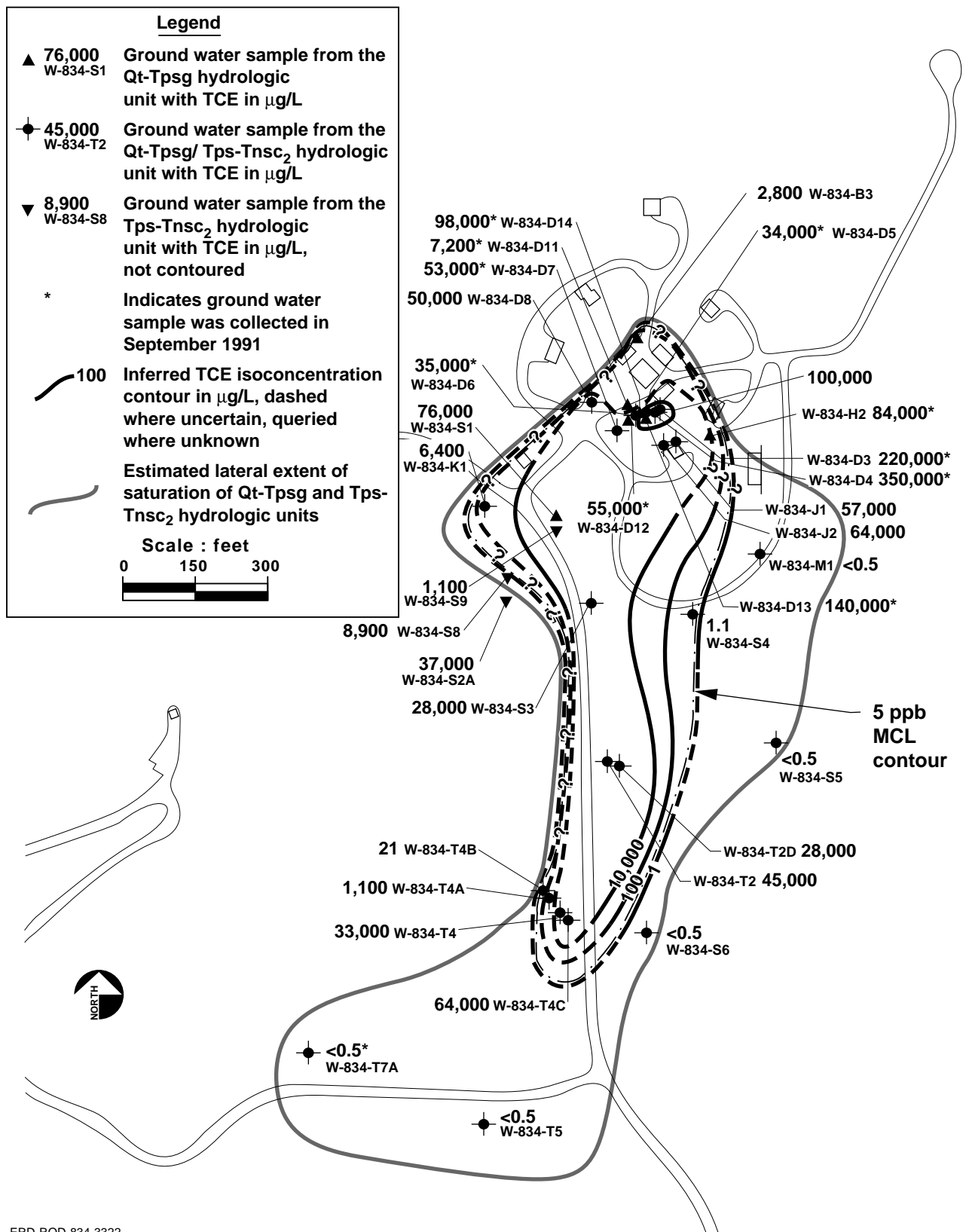
ERD-ROD-834-3320

Figure 3. Functions of the buildings at the Building 834 operable unit.



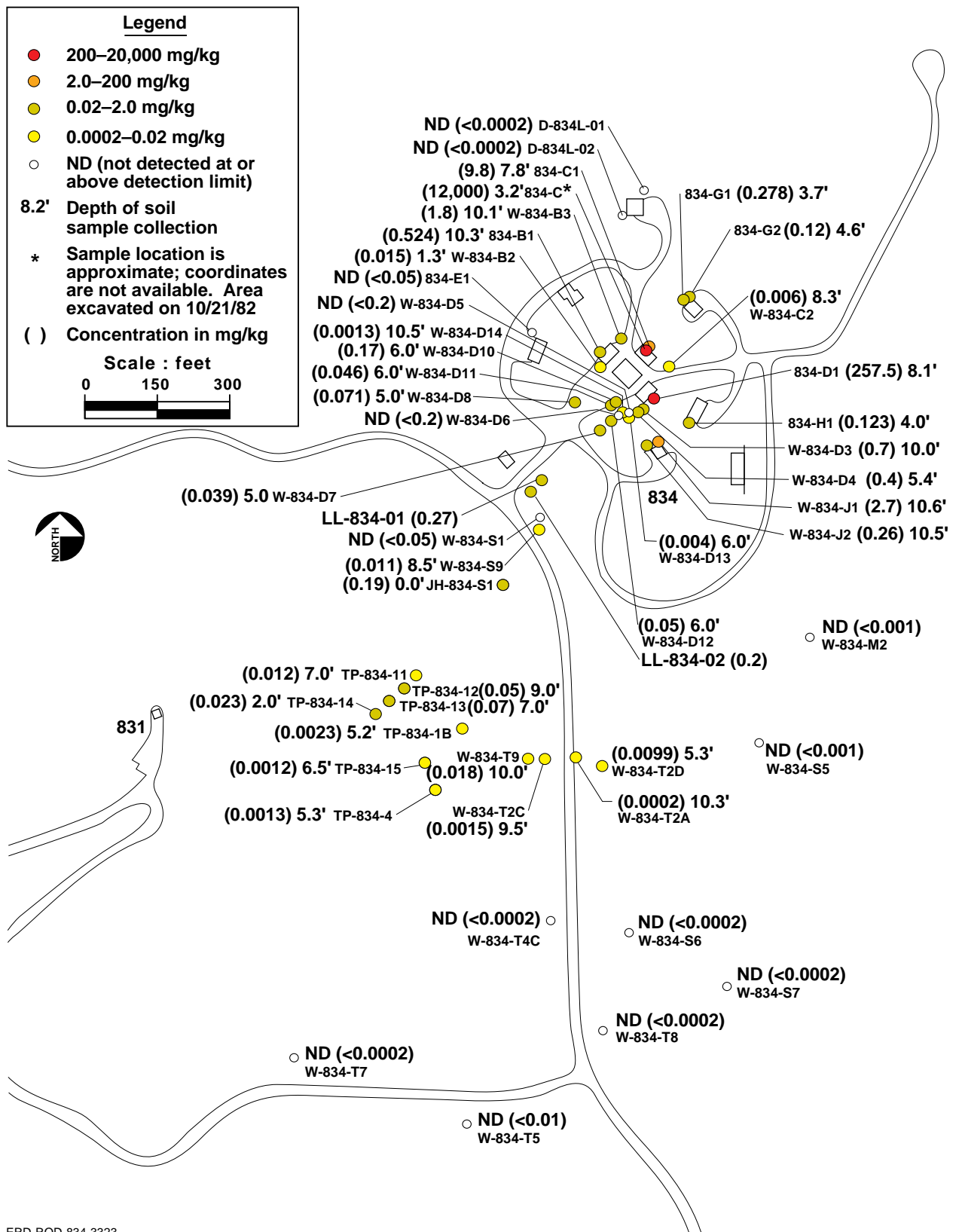
OD-834-3321

Figure 4. Conceptual hydrogeologic model of the Building 834 operable unit.



ERD-ROD-834-3322

Figure 5. Distribution of TCE in perched groundwater in the Qt-Tpsg/Tps-Tns₂ hydrologic units, December 1991.



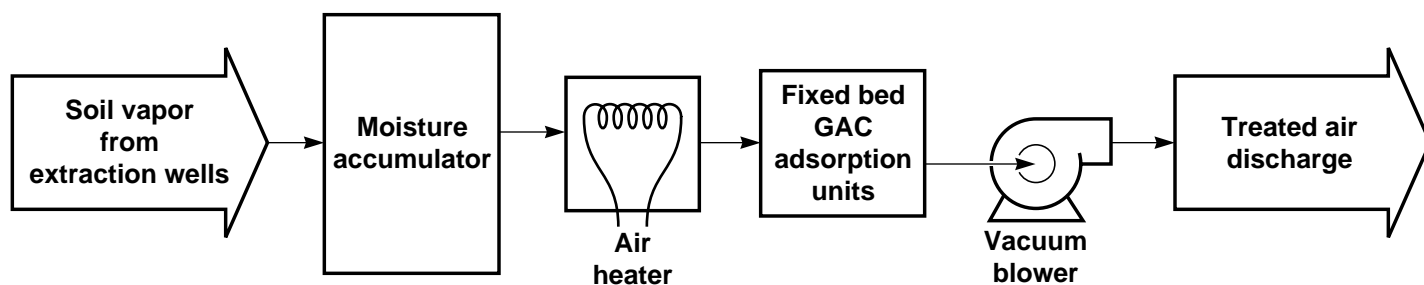
ERD-ROD-834-3323

Figure 6. Maximum TCE concentration, 0 to 12 ft, in soil and rock samples in the Building 834 operable unit.



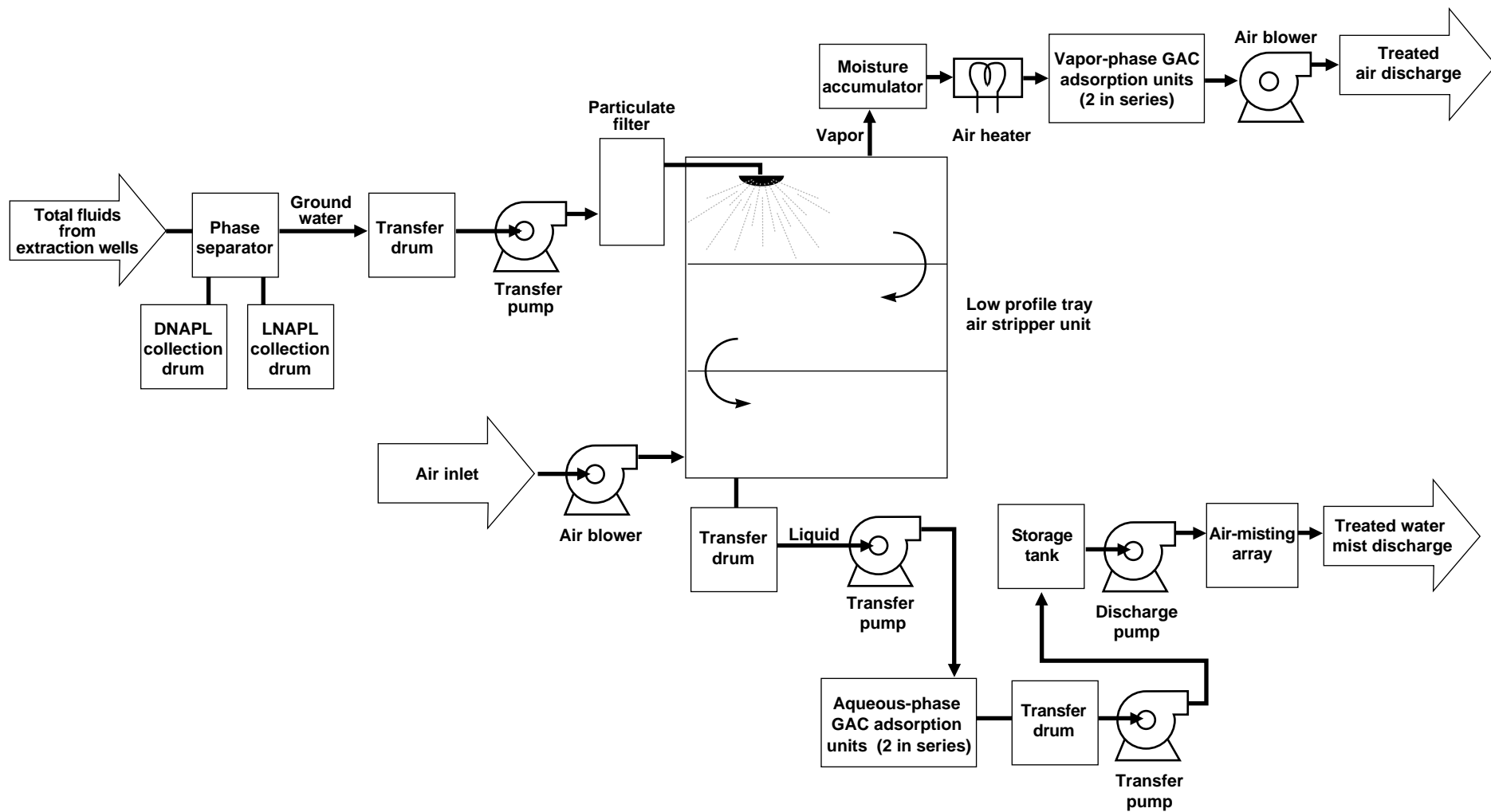
ERD-ROD-834-3325

Figure 8. Vertical distribution of TCE in soil vapor at the Building 834 operable unit (ppm_{v/v}).



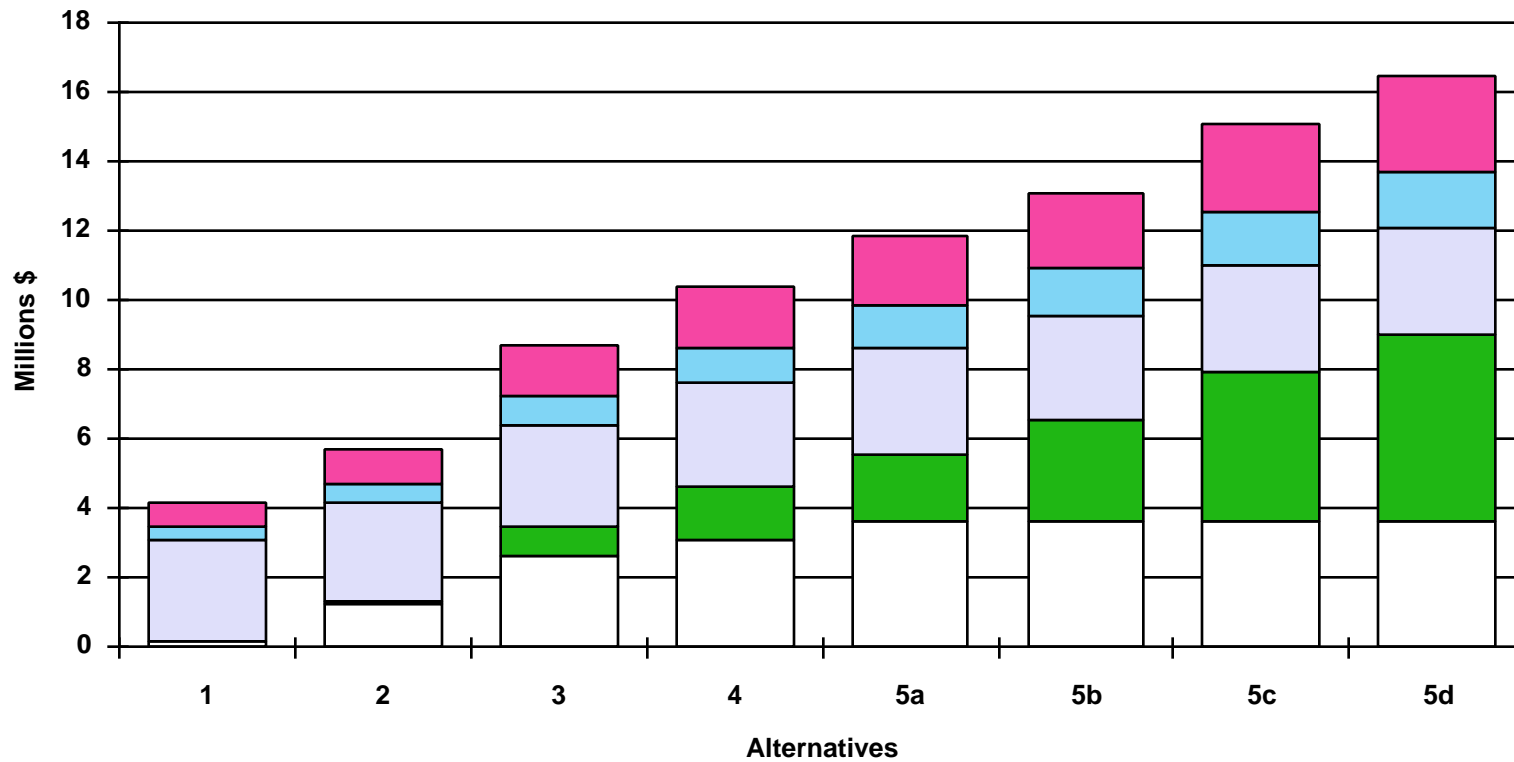
ERD-ROD-834-3326






Figure 9. Soil vapor treatment system.



ERD-ROD-834-3327

Figure 10. Air stripper with aqueous-phase and vapor-phase GAC.



Legend			
Costs		Alternatives	
	Contingency	1	No action
	Lab taxes	2	Inhalation exposure controls, LNAPL recovery, and drainage control
	Monitoring cost	3	Source mass removal by SVE and LNAPL recovery, and drainage control
	O & M		
	Capital costs		
		4	Source mass removal by SVE with dewatering and by LNAPL recovery, and drainage control
		5a, b, c, d	Source mass removal by SVE with dewatering and LNAPL recovery, downgradient dewatering, and drainage control
			a = 5 yr dewatering
			b = 10 yr dewatering
			c = 20 yr dewatering
			d = 30 yr dewatering
Alternative 6: cost not available for innovative technology. BAT SVE costs would be similar to Alternative 3 or 4 if the Basin Plan is amended and similar to Alternative 5 if the Plan is not amended.			

ERD-ROD-834-3328

Figure 11. Building 834 remedial alternative cost summary chart.

Table 1. Contaminants of potential concern in ground water in the Building 834 operable unit.^e

Contaminant	Maximum concentration μg/L (ppb)	Mean concentration ^a	95% UCL ^b μg/L (ppb)
1, 1, 1-Trichloroethane	3.3×10^4	3.02×10^3	1.87×10^4
1, 1-Dichloroethylene	9.0×10^2	2.10×10^1	8.47×10^1
cis-1,2-Dichloroethylene ^c	5.4×10^5	1.62×10^4	1.41×10^5
Acetone	5.5×10^{1d}	NA ^d	5.5×10^{1d}
Benzene	1.4×10^{1d}	NA ^d	1.4×10^{1d}
Chloroform	9.5×10^2	3.31×10^1	1.06×10^2
Ethylbenzene	2.1×10^1	4.59×10^0	1.27×10^1
Methylene chloride	5.1×10^3	2.02×10^2	2.50×10^2
Tetrachloroethylene	6.3×10^3	4.30×10^2	9.08×10^2
Toluene	6.2×10^1	2.13×10^1	5.65×10^1
Trichloroethylene	5.1×10^5	1.38×10^5	1.90×10^5
Trichlorotrifluoroethane	1.3×10^3	2.37×10^1	3.60×10^2
Xylenes (total isomers)	4.0×10^{1d}	NA ^d	4.0×10^{1d}

^a Estimate of the arithmetic mean of the underlying log-normal distribution.

^b UCL = upper confidence limit.

^c The chemical 1, 2-dichloroethylene (1,2-DCE) exists as two isomers, cis-1,2-DCE and trans-1,2-DCE. At various times throughout the 9 years of ground water analysis at Site 300, this chemical has been analyzed for as 1,2-DCE (total), as one or both of the specific isomers, or as all three. When concentration data were available for one or both isomers, we used those values and omitted the less specific analysis for 1,2-DCE (total) from further consideration. The exceptions to this were in cases where the concentration reported for 1,2-DCE (total) was greater than that reported for one or both isomers.

^d This contaminant has only been detected a single time; consequently, neither a mean concentration nor a 95% UCL were calculated. The concentration detected is given for the maximum concentration and the 95% UCL. NA = not applicable.

^e Analytical data originally presented in the SWRI report (data prior to December 31, 1991).

Table 2. Contaminants of potential concern in surface soil (0–0.5 ft) in the Building 834 operable unit.

Contaminant	Maximum concentration mg/kg (ppm)	Mean concentration ^a	95% UCL ^b mg/kg (ppm)
Acetone	7.0×10^{-2}	3.21×10^{-2}	5.63×10^{-2}
Cadmium	1.6×10^1	NA ^c	1.6×10^{1c}
Trichloroethylene	1.9×10^{-1}	2.59×10^{-2}	7.03×10^{-2}
Trichlorofluoromethane	2.1×10^{-2}	5.24×10^{-3}	1.28×10^{-2}
Trichlorotrifluoroethane	9.5×10^{-2}	1.49×10^{-2}	3.66×10^{-2}
Xylenes (total isomers)	5.0×10^{-3}	2.86×10^{-3}	3.55×10^{-3}

^a Estimate of the arithmetic mean of the underlying log-normal distribution.

^b UCL = upper confidence limit.

^c Because there was only a single sample and a single detection of this substance, a 95% UCL could not be calculated. The value given is the only measured concentration. NA = parameter not applicable.

Table 3. Contaminants of potential concern in subsurface soil (>0.5–12.0 ft) at Building 834D.

Contaminant	Maximum concentration mg/kg (ppm)	Mean concentration ^a	95% UCL ^b mg/kg (ppm)
Benzene	2.0×10^{-4c}	NA ^c	2.00×10^{-4c}
Ethylbenzene	1.3×10^{-3}	2.55×10^{-4}	6.16×10^{-4}
Tetrachloroethylene	1.4×10^1	5.95×10^{-1}	1.44×10^0
Toluene	1.2×10^{-3c}	NA ^c	1.20×10^{-3c}
Trichloroethylene	2.6×10^2	2.74×10^1	4.76×10^1
Trichlorofluoromethane	2.0×10^{-1}	3.21×10^{-2}	5.29×10^{-2}
Xylenes (total isomers)	1.7×10^{-2}	4.93×10^{-3}	1.45×10^{-2}

^a Estimate of the arithmetic mean of the underlying log-normal distribution.

^b UCL = upper confidence limit.

^c No statistical calculations were made for this substance. The value given is the maximum measured concentration. NA = parameter not applicable.

Table 4. Compounds other than TCE reported in borehole soil and rock samples from the Building 834 operable unit.

Chemical	Maximum concentration detected in mg/kg (ppm)	No. of detections				
		Perched zone	Perching horizon	Neroly upper sandstone	Neroly aquitard	Neroly lower sandstone
Tetrachloroethylene (PCE)	14	30	11	0	0	0
1,1-Dichloroethylene (1,1-DCE)	0.0037	2	3	0	0	0
1,2-Dichloroethylene (1,2-DCE) (Total)	0.017	17	3	0	0	0
1,1,1-Trichloroethane (1,1,1-TCA)	0.0004	0	2	0	0	0
Trichlorofluoromethane (Freon 11)	0.2	4	1	0	1	0
Trichlorotrifluoroethane (Freon 113)	0.004	10	0	0	0	0
Dibromochloromethane	0.0004	1	0	0	0	0
Ethylbenzene	0.0035	13	1	0	0	0
Benzene	0.0013	11	3	0	0	0
Toluene	0.052	18	4	0	0	0
Xylene isomers	0.017	13	3	0	0	0
Total petroleum hydrocarbons	100	0	1	0	0	0
Chloroform	0.024	11	8	0	0	0
Carbon tetrachloride	0.0009	0	1	0	0	0
Methylene chloride	0.0028	3	0	0	1	0
HMX	0.0002	0	1	0	0	0
RDX	0.02	0	2	0	0	0

Table 5. Maximum concentrations of TCE encountered in soil vapor at the Building 834 operable unit.

Sample location	Depth (ft)	Maximum TCE concentration (ppm _{v/v})
SVS-834-B01	10.2	3,800 and 2,000 ^a
SVS-834-B02	11.8	1,800 and 1,700 ^a
SVS-834-C01	11.5	6,600 and 6,400 ^a
SVS-834-D01	6.0	45 and 43 ^a
SVS-834-D02	12.6	1,200 and 1,200 ^a
SVS-834-D03	16.2	310 and 310 ^a
SVS-834-D04	16.4	1,300 and 1,000 ^a
SVS-834-D05	15.5	270 and 160 ^a
SVS-834-D06	15.0	510
SVS-834-D07	3.0	97
SVS-834-D08	20.0	6,300 and 6,500 ^a
SVS-834-F01	9.4	16
SVS-834-G01	14.3	25
SVS-834-H01	14.7	7
SVS-834-H02	13.7	6,300
SVS-834-J01	10.0	4
SVS-834-J02	14.7	>700
SVS-834-M01	19.2	3.19

Notes:

^a One of these concentrations is a duplicate sample result.

1. A general increase occurred in the concentration of TCE soil vapor with depth in each borehole (Webster-Scholten, 1994). In only 7 out of 22 sampling locations was there a deviation from this pattern. (Every sample was lower in concentration than those collected beneath it.)
2. In only 1 sampling location out of 22 was the maximum concentration at a depth of less than 5 ft. This occurred at location SVS-834-D07, about 18 ft to the northeast of pump station Building 834D. The concentration at a depth of 3 ft was 96.8 ppm_{v/v} (v/v = on a volume-per-volume basis).
3. The overall maximum concentrations at a depth of less than 5 ft were as follows: 120 ppm_{v/v} at 3.5-ft depth, SVS-834-C01, about 10 ft to the southeast of pump station Building 834C; 96.8 ppm_{v/v} at 3-ft depth, SVS-834-D07; and 62.6 ppm_{v/v} at 3-ft depth, SVS-834-B01, about 15 ft to the north of pump station Building 834B.
4. At 6 out of 22 sampling locations, the maximum concentrations were at depths of from 5.1 to 12 ft. These are: SVS-834-B01, SVS-834-B02, SVS-834-C01, SVS-834-D01, and SVS-834-J01.
5. The overall maximum concentrations considering all depths were adjacent to pump station Buildings 834C and D, and about 18 ft west of test cell 834H.
6. The second highest overall maxima at any depth were at pump station Buildings 834B, C, and D.
7. Although concentrations tend to increase with depth, the increases are not identical. Similar sample depths in adjacent sample locations do not necessarily have similar concentrations. The lateral variability in the magnitude of soil vapor concentrations is attributed to the variability in lithologic and moisture content of the perched zone.
8. It is inferred that two mechanisms may be exerting control on the distribution of TCE in soil vapor at the core of the Building 834 operable unit: (1) diffusion of TCE vapor from the upper surface of the TCE plume in ground water; and (2) the "settling" of TCE in soil vapor onto a less permeable surface (in this case the unsaturated/saturated soil interface), due to the density of TCE vapor relative to air.

Table 6. Summary of the fate and transport models applied to estimate human exposure-point concentrations in the Building 834 operable unit.

Media/process release area(s)	Model and/or method	Potential exposure point(s)	Chemicals of concern	Maximum concentration at release area(s)	95% UCL	Estimated exposure-point concentrations	
Fugitive (airborne) dust; contaminants bound to resuspended soil particles							
Data evaluated are from surface soil samples collected throughout the study area.	Mass-loading (Anspaugh et al., 1975).	Throughout the operable unit.	Acetone	0.07 mg/kg ^a	0.0563 mg/kg ^a	1.29 × 10 ⁻⁹ mg/m ^{3b}	
			Cadmium	16 mg/kg ^a	16 mg/kg ^a	3.68 × 10 ⁻⁷ mg/m ^{3b}	
			TCE	0.19 mg/kg ^a	0.0703 mg/kg ^a	1.62 × 10 ⁻⁹ mg/m ^{3b}	
			Freon 11	0.021 mg/kg ^a	0.0128 mg/kg ^a	2.94 × 10 ⁻¹⁰ mg/m ^{3b}	
			Freon 113	0.095 mg/kg ^a	0.0366 mg/kg ^a	8.42 × 10 ⁻¹⁰ mg/m ^{3b}	
			Xylenes (total isomers)	0.005 mg/kg ^a	0.00355 mg/kg ^a	8.17 × 10 ⁻¹¹ mg/m ^{3b}	
Direct contact with surface soil (<0.5 ft).	Measured concentration of contaminant in surface soil.	Throughout the operable unit (Exposure routes: incidental ingestion and direct dermal contact.)	Acetone	0.07 mg/kg ^a	0.0563 mg/kg ^a	5.63 × 10 ⁻² mg/kg ^a	
			Cadmium	16 mg/kg ^a	16 mg/kg ^a	1.60 × 10 ¹ mg/kg ^a	
			TCE	0.19 mg/kg ^a	0.0703 mg/kg ^a	7.03 × 10 ⁻² mg/kg ^a	
			Freon 11	0.021 mg/kg ^a	0.0128 mg/kg ^a	1.28 × 10 ⁻² mg/kg ^a	
			Freon 113	0.095 mg/kg ^a	0.0366 mg/kg ^a	3.66 × 10 ⁻² mg/kg ^a	
			Xylenes (total isomers)	0.005 mg/kg ^a	0.00355 mg/kg ^a	3.55 × 10 ⁻³ mg/kg ^a	
Volatilization of contaminants from subsurface soil to air within a building and to the atmosphere							
Area adjacent to pump station Building 834D.	Volatilization from subsurface soil and diffusion into a building (McKone, 1992).	Inside Building 834D.	Benzene	0.00020 mg/kg ^c	0.00020 mg/kg ^c	5.92 × 10 ⁻⁶ mg/m ^{3d} 3.46 × 10 ⁻⁶ mg/m ^{3e}	
			Ethylbenzene	0.0013 mg/kg ^c	0.000616 mg/kg ^c	5.62 × 10 ⁻⁶ mg/m ^{3d} 5.38 × 10 ⁻⁶ mg/m ^{3e}	
		Volatilization from the soil to the atmosphere (Hwang et al., 1986).	In the vicinity of Building 834D.	PCE	14 mg/kg ^c	1.44 mg/kg ^c	3.64 × 10 ⁻² mg/m ^{3d} 2.29 × 10 ⁻² mg/m ^{3e}
				Toluene	0.0012 mg/kg ^c	0.00120 mg/kg ^c	2.03 × 10 ⁻⁵ mg/m ^{3d} 1.49 × 10 ⁻⁵ mg/m ^{3e}
	TCE			260 mg/kg ^c	47.6 mg/kg ^c	1.32 × 10 ⁰ mg/m ^{3d} 7.98 × 10 ⁻¹ mg/m ^{3e}	
	Freon 11			0.20 mg/kg ^c	0.0529 mg/kg ^c	1.18 × 10 ⁻² mg/m ^{3d} 5.47 × 10 ⁻³ mg/m ^{3e}	
	Xylenes (total isomers)			0.017 mg/kg ^c	0.0145 mg/kg ^c	1.22 × 10 ⁻⁴ mg/m ^{3d} 1.21 × 10 ⁻⁴ mg/m ^{3e}	

Table 6. (Continued)

Media/process release area(s)	Model and/or method	Potential exposure point(s)	Chemicals of concern	Maximum concentration at release area(s)	95% UCL	Estimated exposure-point concentrations
<i>Soil/rock and ground water</i>						
Core of the Building 834 Complex.	Perched zone; VLEACH (U.S. EPA, 1981).	Well CDF-1, completed in the regional aquifer, 4,100 ft down-gradient from the Building 834 Complex and outside the Site 300 boundary.	Primarily TCE; co-contaminants detected in ground water samples in the study area also considered. These include: 1,1-DCE, cis-1,2-DCE, 1,1,1-TCA, acetone, benzene, chloroform, ethylbenzene, methylene chloride, PCE, toluene, Freon 113, and xylenes (total isomers).	510,000 µg/L TCE ^f	Assumed source term for VLEACH is 1,100 mg/L (ppm) TCE	1.6 × 10 ⁻⁴ µg/L TCE (maximum concentration contributed from perched zone). Maximum 70-year average TCE concentration predicted in well CDF-1 from the perched zone is 1.5 × 10 ⁻⁴ mg/L. Concentrations of co-contaminants from the perched zone in the range of 10 ⁻⁹ to 10 ⁻⁴ mg/L.
	Regional aquifer; PLUME (In-Situ, Inc., 1986).	Well CDF-1, completed in the regional aquifer, 4,100 ft down-gradient from the Building 834 Complex and outside the Site 300 boundary.	1,1,1-TCA, chloroform, methylene chloride, PCE, toluene, Freon 113, and TCE.	3.5 µg/L ^f	Assumed source term for PLUME is all detected VOC concentrations from regional aquifer wells: W-834-T1, W-834-T3, and W-831-01 These were treated as instantaneous point sources.	Concentrations of VOCs predicted to arrive at CDF-1 from regional aquifer wells W-031-01, W-834-T1, and W-834-T3 range from 10 ⁻¹³ to 10 ⁻¹² mg/L (ppb). The exposure-point concentrations in ground water withdrawn from CDF-1.

^a Surface soil (0–0.5 ft).
^b Air.
^c Subsurface soil (0.5–12.0 ft).
^d Indoor air.
^e Outdoor air.
^f Ground water.

Table 7. Calculation of excess individual lifetime cancer risk attributable to inhalation of VOCs that volatilize from subsurface soil (>0.5 to 12 ft) to air in the vicinity of Building 834D in the Building 834 operable unit (adult on-site exposure).

Chemical	C _{a(sbs)} (mg/m ³) ^a	PEF(inh) [m ³ /(kg•d)] ^b	Dose(inh) [mg/(kg•d)] ^b	Slope factor for risk (R) (1/[mg/(kg•d)])	Source of information for slope factor ^c	Excess individual 70-year lifetime cancer risk
Benzene	3.46E-06	6.99E-02	2.42E-07	1.00E-01	State of Calif.	2.42E-08
Ethylbenzene	5.38E-06	1.96E-01	1.05E-06	Not carcinogenic	NA ^d	NA ^d
Tetrachloroethylene	2.29E-02	6.99E-02	1.60E-03	5.10E-02	State of Calif.	8.17E-05
Toluene	1.49E-05	1.96E-01	2.92E-06	Not carcinogenic	NA ^d	NA ^d
Trichloroethylene	7.98E-01	6.99E-02	5.58E-02	1.00E-02	State of Calif.	5.58E-04
Trichlorofluoromethane	5.47E-03	1.96E-01	1.07E-03	Not carcinogenic	NA ^d	NA ^d
Xylenes	1.21E-04	1.96E-01	2.38E-05	Not carcinogenic	NA ^d	NA ^d
Σ Risk =						6.40E-04

^a C_{a(sbs)} refers to the concentration (C) of contaminant in air (a) (the exposure medium), which results directly from the presence of contaminant in subsurface soil (sbs).
^b PEF = pathway exposure factor; inh = exposure and/or dose from inhalation.
^c State of Calif. refers to California Environmental Protection Agency (1992).
^d NA = parameter not applicable.

Table 8. Calculation of excess individual lifetime cancer risk attributable to inhalation of VOCs that volatilize from soil into the indoor air of Building 834D in the Building 834 operable unit (adult on-site exposure).

Chemical	C _{VOC(sbs)} (mg/m ³) ^a	PEF(inh) [m ³ /(kg•d)] ^b	Dose(inh) [mg/(kg•d)] ^b	Slope factor for risk (R) (1/[mg/(kg•d)])	Source of information for slope factor ^c	Excess individual 70-year lifetime cancer risk
Benzene	5.92E-06	6.99E-02	4.14E-07	1.00E-01	State of Calif.	4.14E-08
Ethylbenzene	5.62E-06	1.96E-01	1.10E-06	Not carcinogenic	NA ^d	NA ^d
Tetrachloroethylene	3.64E-02	6.99E-02	2.55E-03	5.10E-02	State of Calif.	1.30E-04
Toluene	2.03E-05	1.96E-01	3.98E-06	Not carcinogenic	NA ^d	NA ^d
Trichloroethylene	1.32E+00	6.99E-02	9.23E-02	1.00E-02	State of Calif.	9.23E-04
Trichlorofluoromethane	1.18E-02	1.96E-01	2.31E-03	Not carcinogenic	NA ^d	NA ^d
Xylenes	1.22E-04	1.96E-01	2.39E-05	Not carcinogenic	NA ^d	NA ^d
Σ Risk =						1.05E-03

^a C_{VOC(sbs)} refers to the concentration (C) of volatile organic compound in indoor air (VOC) (the exposure medium), which results directly from the presence of contaminant in subsurface soil (sbs).
^b PEF = pathway exposure factor; inh = exposure and/or dose from inhalation.
^c State of Calif. refers to California Environmental Protection Agency (1992).
^d NA = parameter not applicable.

Table 9. Calculation of excess individual lifetime cancer risk attributable to inhalation of particulates resuspended from contaminated surface soil (0 to 0.5 ft) in the Building 834 operable unit (adult on-site exposure).

Chemical	C _{p(ss)} (mg/m ³) ^a	PEF(inh) [m ³ /(kg•d)] ^b	Dose(inh) [mg/(kg•d)] ^b	Slope factor for risk (R) (1/[mg/(kg•d)])	Route of administration basis for slope factor ^c	Excess individual 70-year lifetime cancer risk
Acetone	1.29E-09	1.96E-01	2.54E-10	Not carcinogenic	NA ^d	NA ^d
Cadmium	3.68E-07	6.99E-02	2.57E-08	1.50E+01	State of Calif.	3.86E-07
Trichloroethylene	1.62E-09	6.99E-02	1.13E-10	1.00E-02	State of Calif.	1.13E-12
Trichlorofluoromethane	2.94E-10	1.96E-01	5.76E-11	Not carcinogenic	NA ^d	NA ^d
Trichlorotrifluoroethane	8.42E-10	1.96E-01	1.65E-10	Not carcinogenic	NA ^d	NA ^d
Xylenes	8.17E-11	1.96E-01	1.60E-11	Not carcinogenic	NA ^d	NA ^d
Σ Risk =						3.86E-07

^a C_{p(ss)} refers to the concentration (C) of contaminant on resuspended particulates in air (p) (the exposure medium), which results directly from the presence of contaminant in surface soil (ss).

^b PEF = pathway exposure factor; inh = exposure and/or dose from inhalation.

^c State of Calif. refers to California Environmental Protection Agency (1992).

^d NA = parameter not applicable.

Table 10. Calculation of excess individual lifetime cancer risk attributable to incidental ingestion and direct dermal contact with contaminated surface soil (0 to 0.5 ft) in the Building 834 operable unit (adult on-site exposure).

Chemical	C _{s(ss)} (mg/kg) ^a	PEF(ing) [kg/(kg•d)] ^b	Dose(ing) [mg/(kg•d)] ^b	Slope factor for risk (R) (1/[mg/(kg•d)])	Source of information for slope factor ^c	Ingestion excess individual 70-year lifetime cancer risk	PEF(derm) [kg/(kg•d)] ^b	Dose(derm) [mg/(kg•d)] ^b	Slope factor for risk (R) (1/[mg/(kg•d)])	Source of information for slope factor ^c	Dermal excess individual 70- year lifetime cancer risk	Total excess individual 70- year lifetime cancer risk
Acetone	5.63E-02	4.89E-07	2.75E-08	Not carcinogenic	NA ^d	NA ^d	5.93E-07	3.34E-08	Not carcinogenic	NA ^d	NA ^d	NA ^d
Cadmium	1.60E+01	1.74E-07	2.78E-06	Not available	Not available	Not available	7.06E-08	1.13E-06	Not available	Not available	Not available	Not available
Trichloroethylene	7.03E-02	1.74E-07	1.22E-08	1.50E-02	State of Calif.	1.84E-10	2.12E-07	1.49E-08	1.50E-02	State of Calif.	2.24E-10	4.07E-10
Trichlorofluoromethane	1.28E-02	4.89E-07	6.25E-09	Not carcinogenic	NA ^d	NA ^d	5.93E-07	7.58E-09	Not carcinogenic	NA ^d	NA ^d	NA ^d
Trichlorotrifluoroethane	3.66E-02	4.89E-07	1.79E-08	Not carcinogenic	NA ^d	NA ^d	5.93E-07	2.17E-08	Not carcinogenic	NA ^d	NA ^d	NA ^d
Xylenes	3.55E-03	4.89E-07	1.74E-09	Not carcinogenic	NA ^d	NA ^d	5.93E-07	2.11E-09	Not carcinogenic	NA ^d	NA ^d	NA ^d
Σ Total risk =												4.07E-10

^a C_{s(ss)} refers to the concentration (C) of contaminant in surface soil (s) (the exposure medium), which results directly from the presence of contaminant in surface soil (ss).

^b PEF = pathway exposure factor; “ing” = exposure and/or dose from ingestion; and “derm” = exposure and/or dose from dermal absorption.

^c State of Calif. refers to California Environmental Protection Agency (1992).

^d NA = parameter not applicable.

Table 11. Calculation of excess individual lifetime cancer risk attributable to residential use of contaminated ground water from the Building 834 operable unit (adult on-site exposure).

Chemical	C _{w(gw)} (mg/L) ^a	House PEF(inh) [L/(kg•d)] ^b	House Dose(inh) [mg/(kg•d)] ^b	Inhalation slope factor for risk (R) (1/[mg/(kg•d)])	Source of infor- mation for slope factor ^c	Inhalation excess individual 70-year lifetime cancer risk	Ground water PEF(ing) [L/(kg•d)] ^b	Ground water Dose(ing) [mg/(kg•d)] ^b	Meat PEF(ing) [L/(kg•d)] ^b	Meat Dose(ing) [mg/(kg•d)] ^b	Milk PEF(ing) [L/(kg•d)] ^b	Milk Dose(ing) [mg/(kg•d)] ^b	Home- grown produce PEF(ing) [L/(kg•d)] ^b	Homegrown produce Dose(ing) [mg/(kg•d)] ^b	Σ Ingestion Dose [mg/(kg•d)]	Slope factor for risk (R) (1/[mg/(kg•d)]))	Source of infor- mation for slope factor ^c	Ingestion excess individual 70-year lifetime cancer risk	Dermal PEF(derm) [L/(kg•d)] ^b	Dermal Dose(derm) [mg/(kg•d)] ^b	Slope factor for risk (R) (1/[mg/(kg•d)]))	Source of infor- mation for slope factor ^c	Dermal excess individual 70-year lifetime cancer risk	Ground water total excess individual 70-year lifetime cancer risk
1,1,1-Trichloroethane	1.32E-08	6.00E-02	7.92E-10	Not carcinogenic	NA ^d	NA ^d	2.74E-02	3.62E-10	3.52E-07	4.65E-15	4.83E-07	6.38E-15	1.07E-03	1.41E-11	3.76E-10	Not carcinogenic	NA ^d	NA ^d	5.58E-03	7.37E-11	Not carcinogenic	NA ^d	NA ^d	NA ^d
1,1-Dichloroethylene	6.00E-11	3.15E-02	1.89E-12	1.20E+00	HEAST	2.27E-12	1.17E-02	7.02E-13	6.59E-08	3.95E-18	9.05E-08	5.43E-18	5.34E-04	3.20E-14	7.34E-13	6.00E-01	IRIS	4.40E-13	1.74E-03	1.04E-13	6.00E-01	IRIS	6.26E-14	2.77E-12
Acetone	3.90E-11	4.79E-02	1.87E-12	Not carcinogenic	NA ^d	NA ^d	2.74E-02	1.07E-12	6.57E-10	2.56E-20	9.01E-10	3.51E-20	2.46E-04	9.59E-15	1.08E-12	Not carcinogenic	NA ^d	NA ^d	1.10E-04	4.29E-15	Not carcinogenic	NA ^d	NA ^d	NA ^d
Benzene	9.90E-12	2.99E-02	2.96E-13	1.00E-01	State of Calif.	2.96E-14	1.17E-02	1.16E-13	6.59E-08	6.52E-19	9.05E-08	8.96E-19	5.34E-04	5.29E-15	1.21E-13	1.00E-01	State of Calif.	1.21E-14	2.00E-03	1.98E-14	1.00E-01	State of Calif.	1.98E-15	4.37E-14
Chloroform	7.48E-11	2.79E-02	2.09E-12	8.10E-02	HEAST	1.69E-13	1.17E-02	8.75E-13	4.55E-08	3.40E-18	6.26E-08	4.68E-18	5.53E-04	4.14E-14	9.17E-13	3.10E-02	State of Calif.	2.84E-14	1.14E-03	8.53E-14	3.10E-02	State of Calif.	2.64E-15	2.00E-13
cis-1,2-Dichloroethylene	9.99E-08	7.28E-02	7.27E-09	Not carcinogenic	NA ^d	NA ^d	2.74E-02	2.74E-09	8.25E-08	8.24E-15	1.13E-07	1.13E-14	1.31E-03	1.31E-10	2.87E-09	Not carcinogenic	NA ^d	NA ^d	2.54E-03	2.54E-10	Not carcinogenic	NA ^d	NA ^d	NA ^d
Ethylbenzene	8.98E-12	5.98E-02	5.37E-13	Not carcinogenic	NA ^d	NA ^d	2.74E-02	2.46E-13	1.61E-06	1.45E-17	2.21E-06	1.98E-17	6.07E-04	5.45E-15	2.52E-13	Not carcinogenic	NA ^d	NA ^d	2.01E-02	1.80E-13	Not carcinogenic	NA ^d	NA ^d	NA ^d
Methylene chloride	1.77E-10	3.35E-02	5.93E-12	3.50E-03	State of Calif.	2.08E-14	1.17E-02	2.07E-12	8.68E-09	1.54E-18	1.19E-08	2.11E-18	5.01E-04	8.87E-14	2.16E-12	1.40E-02	State of Calif.	3.02E-14	4.52E-04	8.00E-14	1.40E-02	State of Calif.	1.12E-15	5.21E-14
Tetrachloroethylene	6.44E-10	2.47E-02	1.59E-11	5.10E-02	State of Calif.	8.11E-13	1.17E-02	7.53E-12	1.23E-06	7.92E-16	1.69E-06	1.09E-15	1.91E-04	1.23E-13	7.66E-12	5.20E-02	EPA Reg IX	3.98E-13	8.49E-03	5.47E-12	5.20E-02	EPAReg IX	2.84E-13	1.49E-12
Toluene	4.01E-11	6.18E-02	2.48E-12	Not carcinogenic	NA ^d	NA ^d	2.74E-02	1.10E-12	6.12E-07	2.45E-17	8.42E-07	3.38E-17	9.06E-04	3.63E-14	1.14E-12	Not carcinogenic	NA ^d	NA ^d	1.11E-02	4.45E-13	Not carcinogenic	NA ^d	NA ^d	NA ^d
Trichloroethylene	1.35E-07	2.57E-02	3.47E-09	1.00E-02	State of Calif.	3.47E-11	1.17E-02	1.58E-09	1.28E-07	1.73E-14	1.77E-07	2.39E-14	4.75E-04	6.41E-11	1.64E-09	1.50E-02	State of Calif.	2.47E-11	2.21E-03	2.98E-10	1.50E-02	State of Calif.	4.48E-12	6.38E-11
Trichlorotrifluoroethane	2.55E-10	6.26E-02	1.60E-11	Not carcinogenic	NA ^d	NA ^d	2.74E-02	6.99E-12	1.65E-06	4.21E-16	2.27E-06	5.79E-16	6.00E-04	1.53E-13	7.14E-12	Not carcinogenic	NA ^d	NA ^d	1.14E-02	2.91E-12	Not carcinogenic	NA ^d	NA ^d	NA ^d
Xylenes	2.84E-11	6.05E-02	1.72E-12	Not carcinogenic	NA ^d	NA ^d	2.74E-02	7.78E-13	1.80E-06	5.11E-17	2.49E-06	7.07E-17	5.73E-04	1.63E-14	7.95E-13	Not carcinogenic	NA ^d	NA ^d	2.17E-02	6.16E-13	Not carcinogenic	NA ^d	NA ^d	NA ^d
Σ Total risk =																							6.84E-11	

^a C_{w(gw)} refers to the concentration (C) of contaminant in water (w). Water is the exposure medium for ingestion and dermal absorption of contaminants, and also is the transfer medium for exposures that result from ingestion of homegrown beef, milk, and fruits and vegetables that are raised on contaminated ground water (gw).

^b PEF = pathway exposure factor; “ing” = exposure and/or dose from ingestion; and “derm” = exposure and/or dose from dermal absorption.

^c HEAST refers to the Health Effects Assessment Summary Tables published by the U.S. EPA (1992b,c); State of Calif. refers to California Environmental Protection Agency (1992); IRIS refers to the Integrated Risk Information System, an on-line computerized database maintained by the U.S. EPA (1992d); and EPA Region IX refers to the U.S. EPA (1993).

^d NA = parameter not applicable.

Table 12. Calculation of noncancer hazard index attributable to inhalation of VOCs that volatilize from subsurface soil (>0.5 to 12 ft) in the vicinity of Building 834D in the Building 834 operable unit (adult on-site exposure).

Chemical	Ca(sbs) (mg/m ³) ^a	PEF(inh) [m ³ /(kg•d)] ^b	Dose(inh) [mg/(kg•d)]	Chronic Reference dose (RfD) [mg/(kg•d)]	Hazard quotient (Dose/RfD)	Source of information for RfD ^c	Comments
Benzene	3.46E-06	1.96E-01	6.78E-07	Not available	Not available	Not available	
Ethylbenzene	5.38E-06	1.96E-01	1.05E-06	1.00E-01	1.05E-05	IRIS	
Tetrachloroethylene	2.29E-02	1.96E-01	4.49E-03	1.00E-02	4.49E-01	IRIS	
Toluene	1.49E-05	1.96E-01	2.92E-06	2.00E-01	1.46E-05	IRIS	
Trichloroethylene	7.98E-01	1.96E-01	1.56E-01	7.35E-03	2.13E+01	State of Calif.	
Trichlorofluoromethane	5.47E-03	1.96E-01	1.07E-03	2.00E-01	5.36E-03	HEAST	Based on RfD (inh)
Xylenes	1.21E-04	1.96E-01	2.38E-05	2.00E+00	1.19E-05	IRIS	
Hazard index = 2.17E+01							

^a Ca(sbs) refers to the concentration (C) of contaminant in air (a) (the exposure medium), which results directly from the presence of contaminant in subsurface soil (sbs).
^b Abbreviations are pathway exposure factor (PEF) and “inh” to indicate exposure and/or dose from inhalation.
^c HEAST refers to the Health Effects Assessment Summary Tables published by the U.S. EPA (1992b,c); State of Calif. refers to California Environmental Protection Agency (1992); IRIS refers to the Integrated Risk Information System, an on-line database maintained by the U.S. EPA (1992d).

Table 13. Calculation of noncancer hazard index attributable to inhalation of VOCs that volatilize from soil into the indoor air of Building 834D in the Building 834 operable unit (adult on-site exposure).

Chemical	CVOC(sbs) (mg/m ³) ^a	PEF(inh) [m ³ /(kg•d)] ^b	Dose(inh) [mg/(kg•d)] ^b	Chronic Reference dose (RfD) [mg/(kg•d)]	Hazard quotient (Dose/RfD)	Source of information for RfD ^c
Benzene	5.92E-06	1.96E-01	1.16E-06	Not available	Not available	Not available
Ethylbenzene	5.62E-06	1.96E-01	1.10E-06	1.00E-01	1.10E-05	IRIS
Tetrachloroethylene	3.64E-02	1.96E-01	7.14E-03	1.00E-02	7.14E-01	IRIS
Trichloroethylene	1.32E+00	1.96E-01	2.59E-01	7.35E-03	3.52E+01	IRIS
Trichlorofluoromethane	1.18E-02	1.96E-01	2.31E-03	2.00E-01	1.15E-02	State of Calif.
Toluene	2.03E-05	1.96E-01	3.98E-06	2.00E-01	1.99E-05	HEAST
Xylenes	1.22E-04	1.96E-01	2.39E-05	2.00E+00	1.20E-05	IRIS
Hazard index = 3.59E+01						

^a CVOC(sbs) refers to the concentration (C) of volatile organic compound in indoor air (voc) (the exposure medium), which results directly from the presence of contaminant in subsurface soil (sbs).
^b Abbreviations are pathway exposure factor (PEF) and “inh” to indicate exposure and/or dose from inhalation.
^c HEAST refers to the Health Effects Assessment Summary Tables published by the U.S. EPA (1992b,c); State of Calif. refers to California Environmental Protection Agency (1992); IRIS refers to the Integrated Risk Information System, an on-line database maintained by the U.S. EPA (1992d).

Table 14. Calculation of noncancer hazard index attributable to inhalation of particulates resuspended from contaminated surface soil (0 to 0.5 ft) in the Building 834 operable unit (adult on-site exposure).

Chemical	C _{p(ss)} (mg/m ³) ^a	PEF(inh) [m ³ /(kg•d)] ^b	Dose(inh) [mg/(kg•d)] ^b	Chronic Reference dose (RfD) [mg/(kg•d)]	Hazard quotient (Dose/RfD)	Source of information for RfD ^c	Comments
Acetone	1.29E-09	1.96E-01	2.54E-10	1.00E-01	2.54E-09	IRIS	
Cadmium	3.68E-07	1.96E-01	7.21E-08	1.00E-03	7.21E-05	IRIS	
Trichloroethylene	1.62E-09	1.96E-01	3.17E-10	7.35E-03	4.31E-08	State of Calif.	
Trichlorofluoromethane	2.94E-10	1.96E-01	5.76E-11	2.00E-01	2.88E-10	HEAST	Based on RfD (inh)
Trichlorotrifluoroethane	8.42E-10	1.96E-01	1.65E-10	3.00E+01	5.50E-12	IRIS	
Xylenes	8.17E-11	1.96E-01	1.60E-11	2.00E+00	8.00E-12	IRIS	
Hazard index = 7.22E-05							

^a C_{p(ss)} refers to the concentration (C) of contaminant on resuspended particulates in air (p) (the exposure medium), which results directly from the presence of contaminant in surface soil (ss).
^b PEF = pathway exposure factor; inh = exposure and/or dose from inhalation.
^c HEAST refers to the Health Effects Assessment Summary Tables published by the U.S. EPA (1992b,c); State of Calif. refers to California Environmental Protection Agency (1992); IRIS refers to the Integrated Risk Information System, an on-line database maintained by the U.S. EPA (1992d).

Table 15. Calculation of noncancer hazard index attributable to incidental ingestion and direct dermal contact with surface soil (0 to 0.5 ft) in the Building 834 operable unit (adult on-site exposure).

Chemical	C _{s(ss)} (mg/kg) ^a	PEF(ing) [kg/(kg•d)] ^b	Dose(ing) [mg/(kg•d)] ^b	PEF(derm) [kg/(kg•d)] ^b	Dose(derm) [mg/(kg•d)] ^b	Σ Dose [mg/(kg•d)]	Chronic Reference dose (RfD) [mg/(kg•d)]	Hazard quotient (Dose/RfD)	Source of information for RfD ^c
Acetone	5.63E-02	4.89E-07	2.75E-08	5.93E-07	3.34E-08	6.09E-08	1.00E-01	6.09E-07	IRIS
Cadmium	1.60E+01	4.89E-07	7.82E-06	1.98E-07	3.17E-06	1.10E-05	1.00E-03	1.10E-02	IRIS
Trichloroethylene	7.03E-02	4.89E-07	3.44E-08	5.93E-07	4.17E-08	7.61E-08	7.35E-03	1.04E-05	State of Calif.
Trichlorofluoromethane	1.28E-02	4.89E-07	6.25E-09	5.93E-07	7.58E-09	1.38E-08	3.00E-01	4.61E-08	IRIS
Trichlorotrifluoroethane	3.66E-02	4.89E-07	1.79E-08	5.93E-07	2.17E-08	3.96E-08	3.00E+01	1.32E-09	IRIS
Xylenes	3.55E-03	4.89E-07	1.74E-09	5.93E-07	2.11E-09	3.84E-09	2.00E+00	1.92E-09	IRIS
Hazard index = 1.10E-02									

^a C_{s(ss)} refers to the concentration (C) of contaminant in surface soil (s) (the exposure medium), which results directly from the presence of contaminant in surface soil (ss).
^b PEF = pathway exposure factor; “ing” = exposure and/or dose from ingestion; and “derm” = exposure and/or dose from dermal absorption.
^c State of Calif. refers to California Environmental Protection Agency (1992); IRIS refers to the Integrated Risk Information System, an on-line computerized database maintained by the U.S. EPA (1992d).

Table 16. Calculation of noncancer hazard index attributable to residential use of contaminated ground water from the Building 834 operable unit.

Chemical	C _{w(gw)} (mg/L) ^a	House PEF(inh) [L/(kg•d)] ^b	House Dose(inh) [mg/(kg•d)] ^b	Chronic Reference Dose (RfD) [mg/(kg•d)]	Hazard index (Dose/RfD)	Source of information RfD (inh) ^{b,c}	Ground water PEF(ing) [L/(kg•d)] ^b	Ground water Dose(ing) [mg/(kg•d)] ^b	Meat PEF(ing) [L/(kg•d)] ^b	Meat Dose(ing) [mg/(kg•d)] ^b	Milk PEF(ing) [L/(kg•d)] ^b	Milk Dose(ing) [mg/(kg•d)] ^b	Home-grown produce PEF(ing) [L/(kg•d)] ^b	Home-grown produce Dose(ing) [mg/(kg•d)] ^b	Dermal PEF(derm) [L/(kg•d)] ^b	Dermal Dose(derm) [mg/(kg•d)] ^b	Σ Dose (mg/(kg•d))	Chronic Reference dose (RfD) [mg/(kg•d)]	Hazard Quotient (Dose/RfD)	Source of information for RfD ^c	Comments
1,1,1-Trichloroethane	1.32E-08	6.00E-02	7.92E-10	3.00E-01	2.64E-09	HEAST	2.74E-02	3.26E-10	3.52E-07	4.65E-15	4.83E-07	6.38E-15	1.07E-03	1.41E-11	5.58E-03	7.37E-11	4.49E-10	9.00E-02	7.63E-09	HEAST	Σ Dose does not inclue inh; Σ HI = (inh + all others)
1,1-Dichloroethylene	6.00E-11	7.33E-02	4.40E-12	NA ^d	NA ^d	NA ^d	2.74E-02	1.64E-12	1.54E-07	9.24E-18	2.11E-07	1.27E-17	1.25E-03	7.50E-14	4.06E-03	2.44E-13	6.36E-12	9.00E-03	7.07E-10	IRIS	
Acetone	3.90E-11	4.79E-02	1.87E-12	NA ^d	NA ^d	NA ^d	2.74E-02	1.07E-12	6.57E-10	2.56E-20	9.01E-10	3.51E-20	2.46E-04	9.59E-15	1.10E-04	4.29E-15	2.95E-12	1.00E-01	2.95E-11	HEAST	
Benzene	9.90E-12	6.96E-02	6.89E-13	NA ^d	NA ^d	NA ^d	2.74E-02	2.71E-13	1.54E-07	152E-18	2.11E-07	2.09E-18	1.25E-03	1.24E-14	4.66E-03	4.61E-14	1.02E-12	Not available	Not available	Not available	
Chloroform	7.48E-11	6.49E-02	4.85E-12	NA ^d	NA ^d	NA ^d	2.74E-02	2.05E-12	1.06E-07	7.93E-18	1.46E-07	1.09E-17	1.29E-03	9.65E-14	2.66E-03	1.99E-13	7.20E-12	1.00E-02	7.20E-10	IRIS	
cis-1,2-Dichloroethylene	9.99E-08	7.28E-02	7.27E-09	NA ^d	NA ^d	NA ^d	2.74E-02	2.74E-09	8.25E-08	8.24E-15	1.13E-07	1.13E-14	1.31E-03	1.31E-10	2.54E-03	2.54E-10	1.04E-08	1.00E-02	1.04E-06	HEAST	
Ethylbenzene	8.98E-12	5.98E-02	5.37E-13	NA ^d	NA ^d	NA ^d	2.74E-02	2.46E-13	1.61E-06	1.45E-17	2.21E-06	1.98E-17	6.07E-04	5.45E-15	2.01E-02	1.80E-13	9.69E-13	1.00E-01	9.69E-12	IRIS	
Methylene chloride	1.77E-10	7.80E-02	1.38E-11	NA ^d	NA ^d	NA ^d	2.74E-02	4.85E-12	2.03E-08	3.59E-18	2.78E-08	4.92E-18	1.17E-03	2.07E-13	1.06E-03	1.88E-13	1.91E-11	6.00E-02	3.18E-10	IRIS	
Tetrachloro-ethylene	6.44E-10	5.75E-02	3.70E-11	NA ^d	NA ^d	NA ^d	2.74E-02	1.76E-11	2.86E-06	1.84E-15	3.95E-06	2.54E-15	4.46E-04	2.87E-13	1.98E-02	1.28E-11	6.77E-11	1.00E-02	6.77E-09	IRIS	
Toluene	4.01E-11	6.18E-02	2.48E-12	NA ^d	NA ^d	NA ^d	2.74E-02	1.10E-12	6.12E-07	2.45E-17	8.42E-07	3.38E-17	9.06E-04	3.63E-14	1.11E-02	4.45E-13	4.06E-12	2.00E-01	2.03E-11	IRIS	
Trichloroethylene	1.35E-07	5.98E-02	8.07E-09	NA ^d	NA ^d	NA ^d	2.74E-02	3.70E-09	3.00E-07	4.05E-14	4.12E-07	5.56E-14	1.11E-03	1.50E-10	5.17E-03	6.98E-10	1.26E-08	7.35E-03	1.72E-06	State of Calif.	
Trichloro-trifluoroethane	2.55E-10	6.26E-02	1.60E-11	NA ^d	NA ^d	NA ^d	2.74E-02	6.99E-12	1.65E-06	4.21E-16	2.27E-06	5.79E-16	6.00E-04	1.53E-13	1.14E-02	2.91E-12	2.60E-11	3.00E+01	8.67E-13	IRIS	
Xylenes	2.84E-11	6.05E-02	1.72E-12	NA ^d	NA ^d	NA ^d	2.74E-02	7.78E-13	1.80E-06	5.11E-17	2.49E-06	7.07E-17	5.73E-04	1.63E-14	2.17E-02	6.16E-13	3.13E-12	2.00E+00	1.56E-12	IRIS	
Hazard index																			= 2.77E-06	IRIS	

^a C_{w(gw)} refers to the concentration (C) of contaminant in water (w). Water is the exposure medium for ingestion of water and dermal absorption of contaminants, and also the transfer medium for exposures that result from ingestion of homegrown beef, milk, and fruits and vegetables that are raised on contaminated ground water (gw).

^b PEF = pathway exposure factor; “ing” = exposure and/or dose from ingestion; and “derm” = exposure and/or dose from dermal absorption.

^c HEAST refers to the Health Effects Assessment Summary Tables published by the U.S. EPA (1992b,c); State of Calif. refers to California Environmental Protection Agency (1992); IRIS refers to the Integrated Risk Information System, an on-line computerized database maintained by the U.S. EPA (1992d); and EPA Region IX refers to the U.S. EPA (1993).

^d NA = parameter not applicable.

Table 17. Estimated incremental lifetime cancer risk and noncancer hazard index associated with potential adult on-site exposure in the Building 834 operable unit (pump station Building 834D: inhalation of VOCs that volatilize from subsurface soil to indoor air).

Chemical	Contaminant concentration $C_{\text{voc(sbs)}} \text{ (mg/m}^3\text{)}^a$	Individual lifetime cancer risk	Hazard index (Dose/RfD)
Benzene	5.92×10^{-6}	4.14×10^{-8}	Not available ^b
Ethylbenzene	5.62×10^{-6}	Not carcinogenic	1.10×10^{-5}
Tetrachloroethylene	3.64×10^{-2}	1.30×10^{-4}	7.14×10^{-1}
Toluene	2.03×10^{-5}	Not carcinogenic	3.52×10^1
Trichloroethylene	1.32×10^0	9.23×10^{-4}	1.15×10^{-2}
Trichlorofluoromethane	1.18×10^{-2}	Not carcinogenic	1.99×10^{-5}
Xylenes	1.22×10^{-4}	Not carcinogenic	1.20×10^{-5}
$\Sigma \text{ Risk} =$		1×10^{-3}	$\Sigma \text{ Hazard index} = 36$

^a $C_{\text{voc(sbs)}}$ refers to the concentration (C) of volatile organic compound in indoor air (voc) (the exposure medium), resulting directly from the presence of contaminant in subsurface soil (sbs).

^b A reference dose (Rfd) is not available.

Table 18. Estimated incremental lifetime cancer risk and noncancer hazard index associated with potential adult on-site exposure in the Building 834 operable unit (vicinity of pump station Building 834D: inhalation of VOCs that volatilize from subsurface soil to air).

Chemical	Contaminant concentration $C_{\text{a(sbs)}} \text{ (mg/m}^3\text{)}^a$	Individual lifetime cancer risk	Hazard index (Dose/RfD)
Benzene	3.46×10^{-6}	2.42×10^{-8}	Not available ^b
Ethylbenzene	5.38×10^{-6}	Not carcinogenic	1.05×10^{-5}
Tetrachloroethylene	2.29×10^{-2}	8.17×10^{-5}	4.49×10^{-1}
Toluene	1.49×10^{-5}	Not carcinogenic	1.46×10^{-5}
Trichloroethylene	7.98×10^{-1}	5.58×10^{-4}	2.13×10^1
Trichlorofluoromethane	5.47×10^{-3}	Not carcinogenic	5.36×10^{-3}
Xylenes	1.21×10^{-4}	Not carcinogenic	1.19×10^{-5}
$\Sigma \text{ Risk} =$		6×10^{-4}	$\Sigma \text{ Hazard index} = 22$

^a $C_{\text{a(sbs)}}$ refers to the concentration (C) of contaminant in air (a) (the exposure medium), resulting directly from the presence of contaminant in subsurface soil (sbs).

^b A reference dose (Rfd) is not available.

Table 19. Estimated incremental lifetime cancer risk and noncancer hazard index associated with potential adult on-site exposure in the Building 834 operable unit (overall operable unit: inhalation of particulates resuspended from surface soil).

Chemical	Contaminant concentration $C_{p(ss)}$ (mg/m ³) ^a	Individual lifetime cancer risk	Hazard index (Dose/RfD)
Acetone	1.29×10^{-9}	Not carcinogenic	2.54×10^{-9}
Cadmium	3.68×10^{-7}	3.86×10^{-7}	7.21×10^{-5}
Trichloroethylene	1.62×10^{-9}	1.13×10^{-12}	4.31×10^{-8}
Trichlorofluoromethane	2.94×10^{-10}	Not carcinogenic	2.88×10^{-10}
Trichlorotrifluoroethane	8.42×10^{-10}	Not carcinogenic	5.50×10^{-12}
Xylenes	8.17×10^{-11}	Not carcinogenic	8.00×10^{-12}
Σ Risk =		4×10^{-7}	Σ Hazard index = 7.2×10^{-5}

^a $C_{p(ss)}$ refers to the concentration (C) of contaminant on resuspended particulates in air (p) (the exposure medium), resulting directly from the presence of contaminant in surface soil (ss).

Table 20. Estimated incremental lifetime cancer risk and noncancer hazard index associated with potential adult on-site exposure in the Building 834 operable unit (overall operable unit: ingestion and dermal adsorption from surface soil).

Chemical	Contaminant concentration $C_{s(ss)}$ (mg/kg) ^a	Individual lifetime cancer risk	Hazard index (Dose/RfD)
Acetone	5.63×10^{-2}	Not carcinogenic	6.09×10^{-7}
Cadmium	1.60×10^1	Not available ^b	1.10×10^{-2}
Trichloroethylene	7.03×10^{-2}	4.07×10^{-10}	1.04×10^{-5}
Trichlorofluoromethane	1.28×10^{-2}	Not carcinogenic	4.61×10^{-8}
Trichlorotrifluoroethane	3.66×10^{-2}	Not carcinogenic	1.32×10^{-9}
Xylenes	3.55×10^{-3}	Not carcinogenic	1.92×10^{-9}
Σ Risk =		4×10^{-10}	Σ Hazard index = 1.1×10^{-2}

^a $C_{s(ss)}$ refers to the concentration (C) of contaminant in surface soil (S) (the exposure medium), resulting directly from the presence of contaminant in surface soil (ss).

^b A slope factor for ingestion or dermal exposure to cadmium is not available.

Table 21. Additive risk and hazard index for adults on site in the Building 834 operable unit (total outdoor exposure only).

Region or source of exposure	Calculated risk associated with the region or source	Calculated hazard index associated with the region or source
Subsurface soil in the vicinity of Building 834D	6×10^{-4}	22
Surface soil throughout the study area (resuspended particulates)	4×10^{-7}	7.2×10^{-5}
Surface soil throughout the study area (ingestion and dermal contact)	4×10^{-10}	1.1×10^{-2}
Σ Risk =	6×10^{-4}	Σ Hazard index = 22

Note:

Exposure within the Building 834D is not included in this summation. Indoor air exposure is considered as a separate scenario and presented in Table 17.

Table 22. Estimated incremental lifetime cancer risk and noncancer hazard index associated with potential residential exposures to contaminated ground water that originates in the Building 834 operable unit (well CDF-1).

	Contaminant concentration $C_{w(gw)}$ (mg/L) ^a	Individual lifetime cancer risk	Hazard index (Dose/RfD)
1,1,1-Trichloroethane	1.32×10^{-8}	Not carcinogenic	7.24×10^{-9}
1,1-Dichloroethylene	6.00×10^{-11}	2.77×10^{-12}	6.89×10^{-10}
Acetone	3.90×10^{-11}	Not carcinogenic	2.85×10^{-11}
Benzene	9.90×10^{-12}	4.37×10^{-14}	Not available ^b
Chloroform	7.48×10^{-11}	2.00×10^{-13}	7.00×10^{-10}
cis-1,2-Dichloroethylene	9.99×10^{-8}	Not carcinogenic	1.01×10^{-6}
Ethylbenzene	8.98×10^{-12}	Not carcinogenic	9.45×10^{-12}
Methylene chloride	1.77×10^{-10}	5.21×10^{-14}	3.10×10^{-10}
Tetrachloroethylene	6.44×10^{-10}	1.49×10^{-12}	6.60×10^{-9}
Toluene	4.01×10^{-11}	Not carcinogenic	1.98×10^{-11}
Trichloroethylene	1.35×10^{-7}	6.38×10^{-11}	1.67×10^{-6}
Trichlorotrifluoroethane	2.55×10^{-10}	Not carcinogenic	8.44×10^{-13}
Xylenes	2.84×10^{-11}	Not carcinogenic	1.53×10^{-12}
Σ Risk =		7×10^{-11}	Σ Hazard index = 2.8×10^{-6}

^a $C_{w(gw)}$ refers to the concentration (C) of contaminant in water (w). Water is the exposure medium for ingestion and dermal absorption of contaminants, and also is the transfer medium for exposures that result from ingestion of homegrown beef, milk, and fruits and vegetables that are raised with contaminated ground water (gw).

^b A reference dose (RfD) is not available.

Table 23. Concentration of TCE in subsurface soil, C_s , associated with a hazard index of 1, cancer risks of 10^{-4} and 10^{-6} , and U.S. EPA Region IX PRG.

	Hazard index (1)	Excess cancer risk (10^{-4})	Excess cancer risk (10^{-6})	Region IX PRG industrial soil	Region IX PRG residential soil
C_s (mg/kg) ^a	2.2 ^b	7.45	7.45×10^{-2}	7.3	3.3

^a C_s (mg/kg) is the calculated concentration of TCE in soil associated with a specific target hazard or risk and represents a potential soil remediation level.

^b The soil vapor concentration at equilibrium with 2.2 mg/kg is 250 ppm_{v/v}.

Table 24. Detailed evaluation of remedial alternatives for the Building 834 operable unit.

Remedial alternative	Evaluation criteria					
	Overall protection of human health and the environment	Compliance with ARARs/RAO	Long-term effectiveness and permanence	Reduction in volume, toxicity, and mobility	Short-term effectiveness	Implementability
Alternative 1 No action	Is not protective of human health and the environment at the Building 834 Complex. Maintains acceptable risk associated with off-site downgradient water-supply wells completed in the regional aquifer.	Does not meet ARARs or the human inhalation RAO.	Does not reduce VOCs in soil vapor to ISVRLs.	Volume, mobility, and toxicity of VOCs not reduced. Subsurface restoration depends on natural degradation, dispersion, and evapotranspiration of VOCs.	No impact to general public. Possible exposure of workers during drilling and monitoring. Use of protective procedures, clothing, and equipment will mitigate risk.	Implementable. Ongoing monitoring would be reduced.
Alternative 2 Inhalation exposure controls, LNAPL recovery, and drainage controls	Exposures to human health risks reduced to EPA-accepted levels inside buildings but not outside. No air emissions. Maintains acceptable risk associated with off-site downgradient water-supply wells completed in the regional aquifer.	Meets all ARARs, and achieves the human inhalation RAO.	Localized infiltration and drainage control will prevent migration of VOCs from source areas. Building ventilation and institutional controls will reduce inhalation health risks to workers in Building 834 Complex buildings to EPA-accepted levels. Does not reduce VOCs in soil vapor to SVRLs.	LNAPLs removed from site. Volume and toxicity of VOCs in soil and ground water not reduced. Infiltration control will reduce mobility. Source mass reduction depends on natural degradation, dispersion, and evapotranspiration of VOCs.	No impact to general public. Short-term impact to workers and access to Building 834 facilities during drilling and construction. Coordinate short-term shutdown of Building 834 facilities. Possible exposure of workers during monitoring, LNAPL recovery, and surface grading. Use of protective procedures, clothing, and equipment will mitigate risk. Costs provided for LNAPL recovery for 2-year duration.	Implementable. Building ventilation would maintain air concentrations at acceptable levels. Hardware is readily available. Standard design and construction techniques and materials used for drainage control. Passive skimmers readily available. Recovered LNAPLs will be managed as a hazardous waste. Low maintenance, long-term effectiveness, low cost.
Alternative 3 Source mass removal by SVE and LNAPL recovery, exposure and drainage controls	Exposures to human health risks reduced to EPA-accepted levels. Adverse impacts to environment from VOCs are substantially reduced. Results in negligible risk to employees and the public from system operation or exposure to air emissions. Maintains acceptable exposure risk associated with off-site downgradient water-supply wells completed in the regional aquifer.	Meets all ARARs, and achieves the human inhalation RAO.	Removes VOCs. SVE and treatment system operated until soil vapor concentrations indicate that SVRLs have been achieved or effectiveness of the technology is expired (estimated 5 year). Mass removal reduces potential for VOC migration to regional aquifer. Spent GAC is regenerated off site. LNAPLs are recycled or disposed of off site. Localized infiltration and drainage control will prevent migration of VOCs from source areas. Building ventilation and institutional controls will reduce inhalation health risks to workers in Building 834 core area buildings.	Volume and toxicity of VOCs reduced by LNAPL recovery, SVE and treatment. VOC vapor migration controlled by SVE. Off-site thermal regeneration of spent GAC destroys VOCs. VOC solubilities and diffusion rates limit total mass removal of VOCs dissolved in ground water or from probable DNAPLs. Natural degradation and evapotranspiration of VOCs continues.	No impact to general public. GAC used to control air emissions from SVE, preventing impact on community. Provides option to conduct pilot tests and implement promising innovative technologies using BAT to ensure that no releases occur. Possible exposure of workers during monitoring, LNAPL recovery, drilling, and construction of piping and treatment systems. Use of protective procedures, clothing, and equipment will mitigate risk. Remediation costed for 5-year duration.	Implementable. SVE and air emissions control using GAC are BAT for removing VOCs from vadose zone. Subsurface hydrogeology is appropriate for SVE. LLNL has permits for construction and operation of SVE treatment system. Services and materials for system construction, O&M, and off-site regeneration of GAC are available. Substantial portion of the system is in place and operating. Skimming LNAPLs is a standard technology. Building ventilation would maintain air concentrations at acceptable levels. Hardware is readily available. Standard design and construction techniques and materials used for drainage control.

Table 24. (Continued)

Remedial alternative	Evaluation criteria					
	Overall protection of human health and the environment	Compliance with ARARs/RAO	Long-term effectiveness and permanence	Reduction in volume, toxicity, and mobility	Short-term effectiveness	Implementability
Alternative 3—Continued			Current industrial health, safety, and hygiene and hazardous materials handling practices are designed to prevent creation of new sources. Provides option to conduct pilot tests and implement promising innovative technologies. Soil vapor and ground water monitoring continue after remediation to ensure permanence of shallow vadose-zone cleanup.	Possible reduction in volume, toxicity, and mobility due to bioremediation augmented by SVE.		
Alternative 4 Source mass removal by SVE with dewatering and by DNAPL and LNAPL recovery, exposure and drainage controls	Exposures to human health risks reduced to EPA-accepted levels. Adverse impacts to environment from VOCs are substantially reduced. Results in negligible risk to employees and the public from system operation or exposure to discharged treated water or air emissions. Maintains acceptable exposure risk associated with off-site downgradient water-supply wells completed in the regional aquifer.	Meets all ARARs, and achieves the human inhalation RAO.	Removes VOCs. Soil vapor extraction and treatment system operated until soil vapor concentrations indicate that SVRLs have been achieved or effectiveness of technology is expired (estimated 5 year). Dewatering increases SVE effectiveness and mass removal. Mass removal reduces potential for VOC migration to regional aquifer. Spent GAC is regenerated off site. DNAPLs and LNAPLs are recycled or disposed of off site. Localized infiltration and drainage control will prevent migration of VOCs from source areas. Building ventilation and institutional controls will reduce inhalation health risks to workers in Building 834 core area buildings. Current industrial health, safety, and hygiene and hazardous materials handling practices are designed to prevent creation of new sources. Provides option to conduct pilot tests and implement promising innovative technologies. Soil vapor and ground water monitoring continue after remediation to ensure permanence of shallow vadose-zone cleanup.	Volume and toxicity of VOCs reduced by SVE, dewatering, and treatment. VOC vapor migration controlled by SVE. VOC mobility at complex reduced by hydraulic control during dewatering. VOC solubilities and diffusion rates limit total mass removal of VOCs dissolved in ground water or from probable DNAPLs. Off-site thermal regeneration of spent GAC destroys VOCs. Natural degradation and evapotranspiration of VOCs continues. Possible reduction in volume, toxicity, and mobility due to bioremediation augmented by SVE. Infiltration control will reduce mobility.	No impact to general public. GAC used to control air emissions from air stripper and SVE, preventing impact on community. Provides capability to conduct pilot tests and implement promising innovative technologies using BAT to ensure that no releases occur. Possible exposure of workers during monitoring, LNAPL recovery, drilling, and construction of piping and treatment systems. Use of protective procedures, clothing, and equipment will mitigate risk. SVE and dewatering costed for 5-year duration.	Implementable. SVE and air emissions control using GAC are BAT for removing VOCs from vadose zone. Subsurface hydrogeology is appropriate for SVE. Dewatering in the core area will expose more soil and enhance mass removal by SVE. LLNL has permits for construction and operation of SVE treatment system. Air stripping is BAT for removing VOCs in ground water. Tray aeration eliminates adverse visual impact of packed towers. Recarbonation system reduces O&M due to carbonate precipitation. Services and materials for system construction, O&M, and off-site regeneration of GAC are available. Substantial portion of the system is in place and operating. Standard requirements for treated ground water discharge would be met. Recovered DNAPLs and LNAPLs will be managed as a hazardous waste. Building ventilation would maintain air concentrations at acceptable levels. Hardware is readily available. Standard design and construction techniques and materials used for drainage control.

Table 24. (Continued)

Remedial alternative	Evaluation criteria					
	Overall protection of human health and the environment	Compliance with ARARs/RAO	Long-term effectiveness and permanence	Reduction in volume, toxicity, and mobility	Short-term effectiveness	Implementability
Alternative 5 Source mass removal by SVE with dewatering and by DNAPL and LNAPL recovery, plume control downgradient by ground water extraction, exposure and drainage controls	Exposures to human health risks reduced to EPA-accepted levels. Adverse impacts to environment from VOCs are substantially reduced. Results in negligible risk to employees and the public from system operation or exposure to discharged treated water or air emissions. Maintains acceptable exposure risk associated with off-site downgradient water-supply wells completed in the regional aquifer.	Meets all ARARs, and achieves the human inhalation RAO.	SVE and treatment system operated until soil vapor concentrations indicate that SRLs may be achieved. Soil confirmation sampling would be conducted to demonstrate that SRLs have been achieved and system would be shut off. Dewatering increases SVE effectiveness and mass removal. Downgradient ground water extraction and treatment operated until TCE concentrations reach asymptotic levels or MCLs, whichever is higher (estimated 30 year). Mass removal reduces potential for VOC migration to regional aquifer. Spent GAC is regenerated off site. DNAPLs and LNAPLs are recycled or disposed off site. Localized infiltration and drainage controls will prevent migration of contaminants of concern from source areas. Building ventilation and institutional controls will reduce inhalation health risks to workers in Building 834 core area buildings. Current industrial health, safety, and hygiene and hazardous materials handling practices are designed to prevent creation of new sources. Provides option to conduct pilot tests and implement promising innovative technologies. Soil vapor and ground water monitoring continue after remediation to ensure permanence of shallow vadose-zone cleanup.	Volume and toxicity of VOCs reduced by LNAPL recovery, SVE and treatment, dewatering and treatment, and downgradient ground water extraction. VOC vapor migration controlled by SVE. VOC mobility reduced by hydraulic control. VOC solubilities and diffusion rates limit total mass removal of VOCs dissolved in ground water or probable DNAPLs. Off-site thermal regeneration of spent GAC destroys VOCs. Natural degradation and evapotranspiration of VOCs continues. Possible reduction in volume, toxicity, and mobility due to bioremediation augmented by SVE. Infiltration control may eventually reduce volume.	No impact to community during construction. Use of GAC to control air emissions from air stripper and SVE will prevent impact on community. Provides capability to conduct pilot tests and implement promising innovative technologies using BAT to ensure that no releases occur. Possible exposure of workers during monitoring, LNAPL recovery, drilling, and construction of piping and treatment systems. Use of protective procedures, clothing, and equipment will mitigate risk. SVE costed for 5-year duration. Ground water extraction costed for 5-, 10-, 20-, and 30-year durations.	Implementable. SVE and air emissions control using GAC are proven remedial technologies for removing VOCs from vadose zone and controlling air emissions. Dewatering in the core area will expose more soil and enhance mass removal by SVE. Subsurface hydrogeology is appropriate for SVE. LLNL has permits for construction and operation of SVE treatment system. Substantial portion of treatment facility is constructed and operating. Operating and discharge permits will be obtained for treatment facility. Air stripping is proven for treatment of VOCs in ground water. Tray aeration eliminates adverse visual impact of packed towers. Recarbonation system reduces O&M due to carbonate precipitation. Services and materials for system construction, O&M, and for off-site regeneration of GAC are readily available. Recovered DNAPLs and LNAPLs will be managed as a hazardous waste. Building ventilation would maintain air concentrations at acceptable levels. Hardware is readily available. Standard design and construction techniques and materials used for drainage control.

Table 24. (Continued)

Remedial alternative	Evaluation criteria					Implementability
	Overall protection of human health and the environment	Compliance with ARARs/RAO	Long-term effectiveness and permanence	Reduction in volume, toxicity, and mobility	Short-term effectiveness	
Alternative 6 ^a Remediation using innovative technology						
a	Innovative technology coupled with soil vapor extraction (enhanced by ground water extraction, as needed) will address all evaluation criteria similarly to Alternative 3 or 4 if perched zone is excluded from Basin Plan.					Innovative technology coupled with soil vapor extraction (and contingent Alternative 5 BAT) will address all evaluation criteria similarly to Alternative 3 or 4 if perched zone is not excluded from Basin Plan.

Table 25. Comparative evaluation of remedial alternatives for the Building 834 operable unit.

Alternative	Overall protection of human health and environment		Compliance with ARARs/RAO	Long-term effectiveness and permanence	Reduction in volume, toxicity, and mobility	Short-term effectiveness	Implementability	Relative Cost	State acceptance	Community acceptance
Alternative 1	Human health:	No	No	Not effective	Dependent on natural degradation	Not effective	Implementable	Low	TBD	TBD
	Environment:	No								
Alternative 2	Human health:		Yes	Effective	Limited reduction in core area LNAPL contamination	Effective	Implementable	Moderate	TBD	TBD
	Inside:	Yes								
	Outside:	No								
	Environment:	No								
Alternative 3	Human health:	Yes	Yes	Effective	Reduction in core area vadose zone and LNAPL contamination	Effective	Implementable	High	TBD	TBD
	Environment:	Yes								
Alternative 4	Human health:	Yes	Yes	Effective	Reduction in core area vadose zone, perched zone, and LNAPL contamination	Very effective	Implementable	High	TBD	TBD
	Environment:	Yes								
Alternative 5	Human health:	Yes	Yes	Very effective	Reduction in core area vadose zone, perched zone, and LNAPL contamination and downgradient perched zone contamination	Very effective	Implementable	Very high ^a	TBD	TBD
	Environment:	Yes								
Alternative 6										
If perched zone excluded from Basin Plan	Same as Alternative 3 or 4							TBD	Same as Alternative 3 or 4	
If perched zone not excluded from Basin Plan	Same as Alternative 5							TBD	Same as Alternative 5	

TBD = To be determined.

^a Overall cost is highly dependent on the required length of pumping time.

Table 26. Soil vapor and ground water monitoring program for the Building 834 operable unit.

Alternative	1				2				3						4						5							
Phase	Soil vapor		Ground water		Soil vapor		Ground water		Soil vapor				Ground water		Soil vapor				Ground water		Soil vapor				Ground water			
Monitoring period (years)	1-5	6-30	1-5	6-30	1-5	6-30	1-5	6-30	1	2-5	6-10	11-30	1	2-5	6-30	1	2-5	6-10	11-30	1-5	6-30	1	2-5	6-10	11-30	1-5	6-30	Comments
Well ID																												
W-834-B2	—	—	A	A	—	—	A	A	Q	B	A	—	Q	B	A	Q	B	A	—	Q	A	Q	B	A	—	Q	B	GWE, SVE
W-834-B3	—	—	A	A	—	—	A	A	Q	B	A	—	Q	B	A	Q	B	A	—	Q	A	Q	B	A	—	Q	B	GWE, SVE
W-834-B4 (new)	NA	NA	NA	NA	NA	NA	NA	NA	Q	B	A	—	Q	B	A	Q	B	A	—	Q	A	Q	B	A	—	Q	B	GWE, SVE
W-834-C2	—	—	A	A	—	—	A	A	Q	B	A	—	A	B	A	Q	B	A	—	A	A	Q	B	A	—	A	B	GWE,* SVE
W-834-C3 (new)	NA	NA	NA	NA	NA	NA	NA	NA	Q	B	A	—	Q	B	A	Q	B	A	—	Q	A	Q	B	A	—	Q	B	GWE, SVE
W-834-D2	—	—	A	A	—	—	A	A	—	—	—	—	Q	A	A	—	—	—	—	Q	A	—	—	—	—	Q	A	Guard well*
W-834-D3	—	—	B	A	—	—	Q	A	Q	B	A	—	Q	B	A	Q	B	A	—	Q	A	Q	B	A	—	Q	B	GWE, SVE
W-834-D4	—	—	B	A	—	—	Q	A	Q	B	A	—	Q	B	A	Q	B	A	—	Q	A	Q	B	A	—	Q	B	GWE, SVE
W-834-D5	—	—	B	A	—	—	Q	A	Q	B	A	—	Q	B	A	Q	B	A	—	Q	A	Q	B	A	—	Q	B	GWE, SVE
W-834-D6	—	—	B	A	—	—	B	A	Q	B	A	—	Q	B	A	Q	B	A	—	Q	A	Q	B	A	—	Q	B	GWE, SVE
W-834-D7	—	—	A	A	—	—	A	A	Q	B	A	—	Q	B	A	Q	B	A	—	Q	A	Q	B	A	—	Q	B	GWE, SVE
W-834-D8	—	—	A	A	—	—	Q	A	Q	B	A	—	Q	B	A	Q	B	A	—	Q	A	Q	B	A	—	Q	B	GWE, SVE
W-834-D9A	—	—	Q	A	—	—	Q	A	—	—	—	—	Q	Q	A	—	—	—	—	Q	A	—	—	—	—	Q	A	Guard well
W-834-D10	—	—	A	A	—	—	A	A	Q	B	A	—	Q	B	A	A	B	A	—	Q	A	Q	B	A	—	A	B	GWE,* SVE
W-834-D11	—	—	A	A	—	—	A	A	Q	B	A	—	Q	B	A	Q	B	A	—	Q	A	Q	B	A	—	Q	B	GWE, SVE
W-834-D12	—	—	A	A	—	—	A	A	Q	B	A	—	Q	B	A	Q	B	A	—	Q	A	Q	B	A	—	Q	B	GWE, SVE
W-834-D13	—	—	A	A	—	—	A	A	Q	B	A	—	Q	B	A	Q	B	A	—	Q	A	Q	B	A	—	Q	B	GWE, SVE
W-834-D14	—	—	A	A	—	—	A	A	Q	B	A	—	Q	B	A	Q	B	A	—	Q	A	Q	B	A	—	Q	B	GWE, SVE
W-834-G3	—	—	A	A	—	—	A	A	—	—	—	—	A	A	A	—	—	—	—	A	A	—	—	—	—	A	A	*
W-834-H2	—	—	A	A	—	—	A	A	—	—	—	—	A	A	A	—	—	—	—	A	A	—	—	—	—	A	A	
W-834-J1	—	—	A	A	—	—	A	A	Q	B	A	—	Q	B	A	Q	B	A	—	Q	A	Q	B	A	—	Q	B	GWE, SVE
W-834-J2	—	—	A	A	—	—	A	A	Q	B	A	—	Q	B	A	Q	B	A	—	Q	A	Q	B	A	—	Q	B	GWE, SVE
W-834-J3 (new)	NA	NA	NA	NA	NA	NA	NA	NA	Q	B	A	—	Q	B	A	Q	B	A	—	Q	A	Q	B	A	—	Q	B	GWE, SVE
W-834-K1	—	—	A	A	—	—	A	A	—	—	—	—	A	A	A	—	—	—	—	A	A	—	—	—	—	A	A	
W-834-M1	—	—	A	A	—	—	A	A	—	—	—	—	A	A	A	—	—	—	—	A	A	—	—	—	—	A	A	
W-834-M2	—	—	A	A	—	—	A	A	—	—	—	—	A	A	A	—	—	—	—	A	A	—	—	—	—	A	A	
W-834-S1	—	—	A	A	—	—	A	A	—	—	—	—	A	A	A	—	—	—	—	A	A	—	—	—	—	Q	B	GWE
W-834-S2	—	—	A	A	—	—	A	A	—	—	—	—	A	A	A	—	—	—	—	A	A	—	—	—	—	A	A	
W-834-S2A	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	To be destroyed
W-834-S3	—	—	A	A	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	To be destroyed
W-834-S4	—	—	A	A	—	—	A	A	—	—	—	—	A	A	A	—	—	—	—	A	A	—	—	—	—	A	A	
W-834-S5	—	—	A	A	—	—	A	A	—	—	—	—	A	A	A	—	—	—	—	A	A	—	—	—	—	A	A	
W-834-S6	—	—	Q	A	—	—	Q	A	—	—	—	—	Q	Q	A	—	—	—	—	Q	A	—	—	—	—	Q	A	
W-834-S7	—	—	A	A	—	—	A	A	—	—	—	—	A	A	A	—	—	—	—	A	A	—	—	—	—	A	A	*

Table 26. (Continued)

Alternative	1				2				3						4						5								
Phase	Soil vapor		Ground water		Soil vapor		Ground water		Soil vapor				Ground water		Soil vapor				Ground water		Soil vapor				Ground water				
Monitoring period (years)	1–5	6–30	1–5	6–30	1–5	6–30	1–5	6–30	1	2–5	6–10	11–30	1	2–5	6–30	1	2–5	6–10	11–30	1–5	6–30	1	2–5	6–10	11–30	1–5	6–30	Comments	
<u>Well ID</u>																													
W-834-S8	—	—	A	A	—	—	A	A	—	—	—	—	A	A	A	—	—	—	—	A	A	—	—	—	—	A	A	GWE	
W-834-S9	—	—	A	A	—	—	A	A	—	—	—	—	A	A	A	—	—	—	—	A	A	—	—	—	—	Q	B		
W-834-S10 (new)	—	—	NA	NA	—	—	B	A	—	—	—	—	B	B	A	—	—	—	—	B	A	—	—	—	—	Q	A		
W-834-S11 (new)	—	—	NA	NA	—	—	B	A	—	—	—	—	B	B	A	—	—	—	—	B	A	—	—	—	—	Q	B		
W-834-S12 (new)	—	—	NA	NA	—	—	B	A	—	—	—	—	B	B	A	—	—	—	—	B	A	—	—	—	—	Q	B		
W-834-T1	—	—	Q	A	—	—	Q	A	—	—	—	—	Q	Q	A	—	—	—	—	Q	A	—	—	—	—	Q	B	Guard well	
W-834-T2	—	—	A	A	—	—	A	A	—	—	—	—	A	A	A	—	—	—	—	A	A	—	—	—	—	Q	B	GWE	
W-834-T2A	—	—	A	A	—	—	A	A	—	—	—	—	A	A	A	—	—	—	—	A	A	—	—	—	—	Q	B	GWE	
W-834-T2B	—	—	A	A	—	—	A	A	—	—	—	—	A	A	A	—	—	—	—	A	A	—	—	—	—	Q	B	GWE	
W-834-T2C	—	—	A	A	—	—	A	A	—	—	—	—	A	A	A	—	—	—	—	A	A	—	—	—	—	Q	B		
W-834-T2D	—	—	A	A	—	—	A	A	—	—	—	—	A	A	A	—	—	—	—	A	A	—	—	—	—	Q	B		
W-834-T3	—	—	Q	A	—	—	Q	A	—	—	—	—	Q	Q	A	—	—	—	—	Q	A	—	—	—	—	Q	B		
W-834-T4	—	—	B	A	—	—	B	A	—	—	—	—	B	B	A	—	—	—	—	B	A	—	—	—	—	Q	B		
W-834-T4A	—	—	B	A	—	—	B	A	—	—	—	—	B	B	A	—	—	—	—	B	A	—	—	—	—	Q	B	GWE	
W-834-T4B	—	—	B	A	—	—	B	A	—	—	—	—	B	B	A	—	—	—	—	B	A	—	—	—	—	Q	B		
W-834-T4C	—	—	B	A	—	—	B	A	—	—	—	—	B	B	A	—	—	—	—	B	A	—	—	—	—	Q	B		
W-834-T5	—	—	Q	A	—	—	Q	A	—	—	—	—	Q	Q	A	—	—	—	—	Q	A	—	—	—	—	Q	B		
W-834-T7A	—	—	Q	A	—	—	Q	A	—	—	—	—	Q	Q	A	—	—	—	—	Q	A	—	—	—	—	Q	B		
W-834-T8	—	—	Q	A	—	—	Q	A	—	—	—	—	Q	Q	A	—	—	—	—	Q	A	—	—	—	—	Q	B	Guard well	
W-834-T9	—	—	Q	A	—	—	Q	A	—	—	—	—	Q	Q	A	—	—	—	—	Q	A	—	—	—	—	Q	B	Guard well	
10 new shallow soil vapor points	B	A	NA	NA	B	A	NA	NA	Q	B	A	A	NA	NA	NA	Q	B	A	A	NA	NA	Q	B	A	A	NA	NA		
<u>Total samples</u>																													
Quarterly			8Q				12Q		29Q				28Q		8Q	29Q				28Q		29Q				40Q			
Biannually	10B		11B		10B		8B		29B				7B		26B	29B				7B		29B				38B			
Annually	10A		30A		49A		10A		29A		49A				29A		10A		17A		52A				29A		10A		

Legend: Q = quarterly, B = biannually, A = annually , — = no sampling, GWE = ground water extraction, SVE = soil vapor extraction, NA = not applicable, * = well is historically dry.

Note: Wells W-834-C2 and W-834 -D10 will be used for GWE if water table rises.

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Table 27. Alternative 6: Capital costs for source mass removal at the core of the Building 834 operable unit using soil vapor extraction enhanced by dewatering.

	Quantity	Unit type	Unit price (1994 \$)	Total (1994 \$)
Capital costs				
<i>Total fluids and soil vapor extraction (SVE) system major equipment costs (MEC)</i>				
Wellhead modifications	9 previously installed			
Additional wellhead modifications	10	each	500	5,000
Electrical supply line	Previously installed			
4-in. PVC piping	700	foot	8.20	5,740
2-1/2-in. PVC piping	700	foot	4.40	3,080
Nalgene tubing	1,000	foot	1.41	1,410
Pneumatic total fluids pumps	3 previously purchased			
Pneumatic total fluids pumps	16	each	2,400	38,400
Pneumatic lines in wells	16	each	250	4,000
Air compressors (7.5 hp)	1	each	5,000	5,000
Air compressor lines in trenches	1,000	foot	1.40	1,400
PVC pipe fittings, unistrut	1	lot	5,000	5,000
Ground water extraction system valves, sampling ports, gauges	3 previously purchased			
Additional GWE valves, sampling ports, gauges	16	well	500	8,000
SVE pitot tubes, vacuum gauges, sampling ports	9 previously installed			
SVE pitot tubes, vacuum gauges, sampling ports	10	well	1,000	10,000
<i>Ground water treatment MEC</i>				
Phase separator (with LNAPL and DNAPL collection drums)	1	each	15,000	15,000
Transfer drum (55 gallons)	3	each	200	600
Air misting storage tank (5,000 gallons)	1	each	5,000	5,000
Transfer pump (1/6 hp)	2	each	300	600
Transfer pump (1-1/2 hp)	2	each	500	1,000
Particulate filter assembly	Previously installed			
Low profile tray air stripper, Model 1321	1	each	13,000	13,000
Knockout drum, demister, carbon bed hookup	1	each	1,100	1,100
Air heater (700 W)	1	each	500	500
Aqueous-phase carbon beds (200 lb)	2	each	500	1,000
Vapor-phase carbon beds (1,000 lb)	2	each	6,000	12,000
Air stripper vapor exhaust blower (2 hp)	1	each	3,500	3,500
Manifold, piping, valves, gauges, sampling ports, totalizer, controllers	1	lot	10,000	10,000

Table 27. Alternative 6: Capital costs for source mass removal at the core of the Building 834 operable unit using soil vapor extraction enhanced by dewatering.

	Quantity	Unit type	Unit price (1994 \$)	Total (1994 \$)
Discharge piping and fittings	Previously installed			
Pipe heating tape	2,000	foot	2	4,000
Addition to existing air misting discharge unit	1	each	10,000	10,000
<i>SVE treatment MEC</i>				
Knockout drum, demister, carbon bed hookup	1	each	1,100	1,100
SVE blower system (10 hp)	Previously installed			
Air heater (700 W)	1	each	500	500
Vapor-phase carbon beds (2,000 lb)	3	each	7,700	23,100
Valves, gauges, sampling ports, controllers	1	lot	10,000	10,000
SVE manifold, piping, exhaust	1	lot	10,000	10,000
Total MEC for exposure control and ground water and SVE treatment systems				209,030
Electrical components (20% of MEC)				41,806
Installation cost (58% of MEC)				121,237
Major equipment installed cost (MEIC)				372,073
<i>Drainage control</i>				
Grading, asphalt paving, curbs, culverts, drainage pipe installation	1	bid	325,500	325,500
<i>Trenching</i>				
Trenching in paved areas	500	foot	40	20,000
Soil analyses and aeration	20	cu. yard	200	4,000
<i>Wells/borings</i>				
Dedicated soil vapor monitoring point	10	point	5,000	50,000
Well installation and development	6	well	10,000	60,000
Soil boring and initial water sample analyses	6	well	8,000	48,000
Pump test	6	well	3,000	18,000
Well destruction	2	well	10,000	20,000
Final confirmatory soil borings and analyses	10	boring	3,000	30,000
<i>Structures</i>				
Equipment building	1	each	300,000	300,000

Table 27. Alternative 6: Capital costs for source mass removal at the core of the Building 834 operable unit using soil vapor extraction enhanced by dewatering.

	Quantity	Unit type	Unit price (1994 \$)	Total (1994 \$)
Geotechnical	1	each	10,000	10,000
Subtotal field costs				1,257,573
Contractor overhead and profit (15% of subtotal field costs)				188,636
Subtotal contractor field costs				1,446,209
LLNL material procurement charge (MPC) (18% of contractor field costs)				260,318
LLNL Protective Services				
Escort service (2 guards for 20 weeks)	200	day	320	64,000
Total field costs (TFC)				1,770,527
Professional environmental services				
Design				50,000
Permitting				30,000
Start-up labor and analyses				40,000
SVE tests				20,000
SVE performance evaluation				50,000
Subtotal professional environmental services				190,000
LLNL MPC (9.7% of professional environmental services)				18,430
Total professional environmental services				208,430

Table 27. Alternative 6: Capital costs for source mass removal at the core of the Building 834 operable unit using soil vapor extraction enhanced by dewatering.

	Quantity	Unit type	Unit price (1994 \$)	Total (1994 \$)
LLNL ERD team				
Full time employee	1	year	120,000	120,000
Total LLNL ERD team				120,000
LLNL technical support services				
LLNL Plant Engineering planning and Title I, II, and III services (33% of TFC)				584,274
Implementation of institutional controls				50,000
Total LLNL support services				634,274
Building ventilation system modification major equipment costs (MEC)				
Building 834A	1	each	10,000	10,000
Building 834D	1	each	5,000	5,000
Building 834J	1	each	4,500	4,500
Building 834O	1	each	4,500	4,500
Seal cracks/epoxy-coat floors				20,000
Total building ventilation retrofits				44,000
Remedial Design Report/Treatability study	1	each	300,000	300,000
Total capital costs (TCC)				3,077,231

Operation and Maintenance Costs

Fixed annual O&M costs for SVE

Electricity	64,700	kw • h	0.07	4,529
Electrical capacity charge	8.2	kw	36	295
Project management	300	hour	75	22,500
System optimization, engineer	400	hour	75	30,000
Well field optimization, hydrogeologist	400	hour	68	27,200
Operating labor	250	hour	55	13,750
Clerical	200	hour	45	9,000
SVE air permit compliance reporting (monthly)	12	report	2,000	24,000

Table 27. Alternative 6: Capital costs for source mass removal at the core of the Building 834 operable unit using soil vapor extraction enhanced by dewatering.

	Quantity	Unit type	Unit price (1994 \$)	Total (1994 \$)
Total fixed annual SVE O&M costs				131,274
Total present worth of fixed O&M for soil vapor extraction, years 1–5 (factor = 4.52)				593,359
<i>Fixed annual O&M costs for dewatering</i>				
Electricity	93,000	kw • h	0.07	6,510
Electrical capacity charge	11.8	kw	36	425
Project management	200	hour	75	15,000
System optimization, engineer	300	hour	75	22,500
Well field optimization, hydrogeologist	300	hour	68	20,400
Operating labor	500	hour	55	27,500
Clerical	200	hour	45	9,000
Ground water treatment system analyses (water only)	12	event	500	6,000
Ground water treatment air permit compliance reporting (monthly)	12	report	2,000	24,000
Ground water discharge reporting (monthly)	12	report	2,000	24,000
Maintenance (10% of MEIC)				37,207
Total fixed annual dewatering and plume control O&M costs				192,542
Total present worth of fixed O&M for ground water extraction, years 1–5 (factor = 4.52)				870,290
Total present worth of fixed O&M costs				1,463,650

Variable operating costs for source mass removal and plume control***Annual costs, year 1***

SVE replacement of GAC	17,860	lb	2.30	41,078
Ground water treatment system replacement of vapor GAC	3,440	lb	2.30	7,912
Ground water treatment system replacement of aqueous GAC	40	lb	2.30	92

Table 27. Alternative 6: Capital costs for source mass removal at the core of the Building 834 operable unit using soil vapor extraction enhanced by dewatering.

	Quantity	Unit type	Unit price (1994 \$)	Total (1994 \$)
SVE air sampling	36	sample	100	3,600
Ground water treatment system air sampling	36	sample	100	3,600
Total annual costs, year 1				56,282
Total present worth, year 1 (factor = 0.97)				54,594
Annual costs, year 2				
SVE replacement of GAC	3,040	lb	2.30	6,992
Ground water treatment system replacement of vapor GAC	1,720	lb	2.30	3,956
Ground water treatment system replacement of aqueous GAC	40	lb	2.30	92
SVE air sampling	36	sample	100	3,600
Ground water treatment system air sampling	36	sample	100	3,600
Total annual costs, year 2				18,240
Total present worth, year 2 (factor = 0.93)				16,963
Annual costs, year 3				
SVE replacement of GAC	1,985	lb	2.30	4,566
Ground water treatment system replacement of vapor GAC	1,720	lb	2.30	3,956
Ground water treatment system replacement of aqueous GAC	40	lb	2.30	92
SVE air sampling	36	sample	100	3,600
Ground water treatment system air sampling	36	sample	100	3,600
Total annual costs, year 3				15,814
Total present worth, year 3 (factor = 0.90)				14,232
Annual costs, year 4				
SVE replacement of GAC	860	lb	2.30	1,978
Ground water treatment system replacement of vapor GAC	1,720	lb	2.30	3,956
Ground water treatment system replacement of aqueous GAC	40	lb	2.30	92
SVE air sampling	36	sample	100	3,600
GWT air sampling	36	sample	100	3,600

Table 27. Alternative 6: Capital costs for source mass removal at the core of the Building 834 operable unit using soil vapor extraction enhanced by dewatering.

	Quantity	Unit type	Unit price (1994 \$)	Total (1994 \$)
Total annual costs, year 4				13,226
Total present worth, year 4 (factor = 0.87)				11,507
<i>Annual costs, year 5</i>				
SVE replacement of GAC	480	lb	2.30	1,104
Ground water treatment system replacement of vapor GAC	1,720	lb	2.30	3,956
Ground water treatment system replacement of aqueous GAC	40	lb	2.30	92
SVE air sampling	36	sample	100	3,600
GWT air sampling	36	sample	100	3,600
Total annual costs, year 5				12,352
Total present worth, year 5 (factor = 0.84)				10,376
Total present worth of variable operating costs				107,671
Total present worth of fixed and variable O&M costs				1,571,321

Ground water monitoring

Annual costs, years 1–5

Quarterly water level measurements	52	well	55	2,860
Quarterly ground water monitoring and analyses	28	well	640	17,920
Biannual ground water monitoring and analyses	7	well	320	2,240
Annual ground water monitoring and analyses	17	well	160	2,720
Maintenance of ground water sampling system	52	well	430	22,360
Quarterly monitoring report	4	report	15,000	60,000
Project management	500	hour	75	37,500
Hydrogeologist	200	hour	68	13,600
Clerical	200	hour	45	9,000
Total annual costs, years 1–5				168,200
Total present worth, years 1–5 (factor = 4.52)				760,264

Table 27. Alternative 6: Capital costs for source mass removal at the core of the Building 834 operable unit using soil vapor extraction enhanced by dewatering.

	Quantity	Unit type	Unit price (1994 \$)	Total (1994 \$)
Annual costs, years 6–30				
Quarterly water-level measurements	52	well	55	2,860
Annual ground water monitoring and analyses	52	well	160	8,320
Maintenance of ground water sampling system	52	well	430	22,360
Quarterly monitoring report	4	report	15,000	60,000
Project management	500	hour	75	37,500
Hydrogeologist	200	hour	68	13,600
Clerical	200	hour	45	9,000
Total annual costs, years 6–30				153,640
Total present worth, years 6–10 (factor = 3.80)				583,832
Total present worth, years 11–15 (factor = 3.20)				491,648
Total present worth, years 16–20 (factor = 2.69)				413,292
Total present worth, years 21–25 (factor = 2.27)				348,763
Total present worth, years 26–30 (factor = 1.91)				293,452
Total present worth, years 6–30				2,130,987
Total present worth of ground water monitoring for 30 years				2,891,251

Soil vapor monitoring**Annual costs, year 1**

Quarterly soil vapor monitoring and analyses from extraction wells	19	well	400	7,600
Quarterly shallow soil vapor point monitoring and analyses	10	point	400	4,000
Total annual costs, year 1				11,600
Total present worth, year 1 (factor = 0.97)				11,252

Annual costs, years 2–5

Table 27. Alternative 6: Capital costs for source mass removal at the core of the Building 834 operable unit using soil vapor extraction enhanced by dewatering.

	Quantity	Unit type	Unit price (1994 \$)	Total (1994 \$)
Biannual soil vapor monitoring and analyses from extraction wells	19	well	200	3,800
Biannual shallow soil vapor point monitoring and analyses	10	point	200	2,000
Total annual costs, years 2–5				5,800
Total present worth, years 2–5 (factor = 3.55)				20,590
Annual costs, years 6–10				
Annual soil vapor monitoring and analyses from extraction wells	19	well	100	1,900
Annual shallow soil vapor point monitoring and analyses	10	point	100	1,000
Total annual costs, years 6–10				2,900
Total present worth, years 6–10 (factor = 3.80)				11,020
Annual costs, years 11–30				
Annual shallow soil vapor point monitoring and analyses	10	point	100	1,000
Total annual costs, years 11–30				1,000
Total present worth, years 11–15 (factor = 3.20)				3,200
Total present worth, years 16–20 (factor = 2.69)				2,690
Total present worth, years 21–25 (factor = 2.27)				2,270
Total present worth, years 26–30 (factor = 1.91)				1,910
Total present worth for soil vapor monitoring for 30 years				52,932
Subtotal present worth of Alternative 6				7,592,735
LLNL General & Administrative Tax (7.5%)				569,455
Subtotal				8,162,190
LLNL Lab-Directed Research & Development Tax (6.0%)				489,731

Table 27. Alternative 6: Capital costs for source mass removal at the core of the Building 834 operable unit using soil vapor extraction enhanced by dewatering.

	Quantity	Unit type	Unit price (1994 \$)	Total (1994 \$)
Subtotal				8,651,921
Contingency (20%)				1,730,384
Total present worth of Alternative 6				10,382,306

Table 28. ARARs for the selected interim remedy at the Building 834 operable unit.

Action	Source	Description	Application to the selected remedy
Extraction of soil vapor and dewatering of perched water-bearing zone	<i>State:</i> Chapter 15, CCR, Title 23, Sections 2550.7, 2550.10. (Applicable)	Requires monitoring of the effectiveness of remedial actions.	During and after completion of the selected interim remedy, concentrations of contaminants in <i>in situ</i> soil vapor and ground water will be measured.
Discharge of treated ground water	<i>State:</i> SWRCB Resolution 68-16 (Antidegradation policy). (Applicable)	Requires that high quality surface and ground water be maintained to the maximum extent possible.	In the context of the selected interim remedy, this is applicable only to discharges of treated ground water from the misting towers. The compliance standards for discharge water are contained in the current Substantive Requirements issued by the RWQCB for the Building 834 operable unit.
Discharge of treated soil vapor	<i>Local:</i> San Joaquin Unified Air Pollution Control District (SJUAPCD) Rules and Regulations, Rules 463.5 and 2201. (Applicable)	Regulates nonvehicular sources of air contaminants.	During the selected interim remedy, contaminated soil vapor will be treated with GAC or equivalent technologies and discharged to the atmosphere. The compliance standards for treated soil vapor are contained in the current Authority To Construct and subsequent Permit to Operate issued by the SJUAPCD.

Table 28. (Continued)

Action	Source	Description	Application to the selected remedy
Disposition of hazardous waste	<p><i>State:</i> Health and Safety Code, Sections 25100-25395, CCR, Title 22, ch. 30: Minimum Standards for Management of Hazardous and Extremely Hazardous Wastes. (Applicable)</p>	<p>Controls hazardous wastes from point of generation through accumulation, transportation, treatment, storage, and ultimate disposal.</p>	<p>For the selected interim remedy, this ARAR applies primarily to spent GAC vessels.</p>
Protection of endangered species	<p><i>Federal:</i> Endangered Species Act of 1973, 16 USC Section 1531 et seq. 50 CFR Part 200, 50 CFR Part 402 [40 CFR 257.3-2]. (Applicable)</p> <p><i>State:</i> California Endangered Species Act, California Department of Fish and Game Sections 2050-2068. (Applicable)</p>	<p>Requires that facilities or practices not cause or contribute to the taking of any endangered or threatened species of plants, fish, or wildlife. NEPA implementation requirements apply.</p>	<p>Prior to any well installation, facility construction, or similar potentially disruptive activities, wildlife surveys will be conducted and mitigation measures implemented if required.</p>

Acronyms

AOS	Adult On Site
ARARs	Applicable or Relevant and Appropriate Requirements
BAT	Best Available Technology
Cal-EPA	State of California, Environmental Protection Agency
CAREs	Citizens Against a Radioactive Environment
CCR	California Code of Regulations
CDF	California Department of Forestry
CDI	Chronic Daily Intake
CERCLA	Comprehensive Environmental Response, Compensation, and Liability Act of 1980
CFR	Code of Federal Regulations
CPF	Cancer Potency Factor
DCE	Dichloroethylene
DNAPLs	Dense Nonaqueous Phase Liquids
DOE	Department of Energy
DTSC	Department of Toxic Substances Control
ECAO	Environmental Criteria Assessment Office
FFA	Federal Facility Agreement
FS	Feasibility Study
GAC	Granular Activated Carbon
GSA	General Services Area
HE	High Explosives
HEAST	Health Effects Assessment Summary Tables
HI	Hazard Index
HQ	Hazard Quotient
IRIS	Integrated Risk Information System
ISVRL	Interim Soil Vapor Restoration Level
LLNL	Lawrence Livermore National Laboratory
LNAPLs	Light Nonaqueous Phase Liquids
LOAEL	Lowest-Observed-Adverse-Effect-Level
MCLs	Maximum Contaminant Levels

NCP	National Contingency Plan
NEPA	National Environmental Policy Act
NOAEL	No-Observed-Adverse-Effect-Level
NPL	National Priorities List
O&M	Operations and Maintenance
OU	Operable Unit
PCE	Tetrachloroethylene
PEFs	Pathway Exposure Factors
PP	Proposed Plan
ppm _{v/v}	Parts Per Million on a Volume-to-Volume Basis
PRGs	Preliminary Remediation Goals
QA	Quality Assurance
QC	Quality Control
Qt	Quaternary Terrace Deposits
RAGS	Risk Assessment Guidance for Superfund
RAOs	Remedial Action Objectives
RCRA	Resource Conservation and Recovery Act
RES	Residential Exposure
RfD	Reference Dose
ROD	Record of Decision
RWQCB	Regional Water Quality Control Board
SARA	Superfund Amendments and Reauthorization Act
SITE	Superfund Innovative Technology Evaluation
SJUAPCD	San Joaquin Unified Air Pollution Control District
SVE	Soil Vapor Extraction
SVS	Soil Vapor Survey
SWRCB	State Water Resources Control Board
SWRI	Site Wide Remedial Investigation Report
T-BOS	Tetra 2-ethylbutylorthosilicate
TBC	To Be Considered
TBD	To Be Determined
TCA	Trichloroethane

TCE	Trichloroethylene
Tnbs ₁	Miocene Neroly Formation Lower Blue Sandstone
Tnbs ₂	Miocene Neroly Formation Upper Blue Sandstone
TPH	Total Petroleum Hydrocarbons
Tpsg	Pliocene Nonmarine Unit (Gravel Facies)
U.S. EPA	United States Environmental Protection Agency
UCLs	Upper Confidence Limits
U.S. DOE	United States Department of Energy
VOCs	Volatile Organic Compounds